

1926

Bulletin 135

March, 1926

# Potato Diseases and Their Control

M. F. Barrus and Charles Chupp



Cornell Extension Bulletin

Published by the New York State College of Agriculture  
at Cornell University, Ithaca, New York

C. E. Ladd, Director of Extension Service

Published and distributed in furtherance of the purposes provided for  
in the Act of Congress of May 8, 1914

# CONTENTS

|                                                           | PAGE |
|-----------------------------------------------------------|------|
| Control measures.....                                     | 4    |
| Selecting seed from the bin.....                          | 4    |
| Seed treatment.....                                       | 6    |
| Disinfection.....                                         | 6    |
| Greening, or sprouting, seed tubers.....                  | 14   |
| Cutting the seed.....                                     | 15   |
| Application of chemicals to the soil to prevent scab..... | 15   |
| Soil temperature at planting time.....                    | 16   |
| Rotation.....                                             | 16   |
| Location of field for seed potatoes.....                  | 16   |
| Roguing.....                                              | 17   |
| Application of a fungicide to the vines.....              | 19   |
| Spraying.....                                             | 20   |
| Dusting.....                                              | 29   |
| Storage.....                                              | 32   |
| The seed plot.....                                        | 33   |
| Indexing tubers.....                                      | 36   |
| Degeneration diseases.....                                | 38   |
| Mosaic.....                                               | 39   |
| Leaf roll.....                                            | 43   |
| Spindle tuber.....                                        | 49   |
| Yellow dwarf.....                                         | 51   |
| Streak.....                                               | 55   |
| Spinach leaf.....                                         | 56   |
| Leaf and stalk diseases.....                              | 57   |
| Late blight.....                                          | 57   |
| Early blight.....                                         | 64   |
| Tipburn and hopper burn.....                              | 67   |
| Leaf blotch.....                                          | 69   |
| Arsenical injury.....                                     | 70   |
| Frost necrosis of foliage.....                            | 70   |
| Rhizoctonia.....                                          | 71   |
| Wilt.....                                                 | 78   |
| Fusarium wilt and tuber rot.....                          | 83   |
| Brown rot.....                                            | 85   |
| Black leg.....                                            | 86   |
| Tuber diseases.....                                       | 90   |
| Common scab.....                                          | 90   |
| Powdery scab.....                                         | 96   |
| Skin spot.....                                            | 99   |
| Silver scurf.....                                         | 100  |
| Wart.....                                                 | 101  |
| Storage dry rots.....                                     | 104  |
| Black-heart.....                                          | 106  |
| Frost necrosis.....                                       | 109  |
| Net necrosis.....                                         | 113  |
| Sprain.....                                               | 113  |
| Secondary tuber formation.....                            | 114  |
| Spindling sprout.....                                     | 115  |
| Sunburn.....                                              | 117  |
| Sun-scald.....                                            | 117  |
| Lightning injury.....                                     | 117  |
| Potash hunger.....                                        | 118  |
| Giant hills.....                                          | 119  |
| Enlarged lenticels.....                                   | 119  |
| Hollow-heart.....                                         | 120  |
| Growth cracks.....                                        | 121  |
| Knobby tubers.....                                        | 122  |

# POTATO DISEASES AND THEIR CONTROL

M. F. BARRUS AND CHARLES CHUPP

This bulletin aims to give county agents and potato growers, especially growers of certified seed, information regarding the nature, the cause, the distribution, the economic importance, and the control of potato diseases in New York State. New information is being obtained every year on potato diseases so that no bulletin or book on the subject can long remain up-to-date.

Fortunately not all the diseases described in this bulletin affect all the potato crop at one time. But, it not uncommonly happens that several diseases may be present in a field, and that throughout the State a large number of diseases may occur within a given season. Some diseases, as brown rot and powdery scab, occur rarely in the State; while others, as streak, affect so few plants as to be unimportant, although found year after year. On the other hand, late blight, although it does not occur every year, destroys vines and tubers of so many plants and spreads so rapidly that it is regarded as one of the worst diseases of potatoes. Degeneration diseases, as mosaic and leaf roll, are not greatly feared since they merely dwarf the plants and seldom affect all the vines in a field; in reality, however, they cause a greater reduction in yield than does late blight. This is because they occur year after year without attracting the attention of the grower.

The loss caused by all potato diseases in the State has not been determined but it certainly must be large, for, if every year all potatoes in the State were healthy, there would be a material increase in yield. This does not mean that it would pay the grower to attempt a control of all the troubles. Some cause too little loss to make control worth while. Nevertheless, it is more profitable to follow a seasonal schedule for the control of diseases than to practice only one measure. For instance, it is not so profitable to spray potatoes having 10 or 20 per cent of leaf-roll as it is to spray those that are healthy. The use of selected seed will bring greater returns if the seed has been treated and if the vines have been protected by a fungicide than if these practices are neglected. The grower must consider the protection of his crop throughout the season by the application of all necessary and practical control measures, if he is to obtain the greatest benefits from the application of any one. This should not be interpreted to mean that all the control measures outlined in the following pages should be applied by all growers. Each grower must determine from his experience and knowledge of potato troubles which measures are applicable to the existing conditions and apply those thoroughly. Thoroughness is all important in controlling diseases. When control measures are only half-heartedly applied, the results usually are disappointing.

## CONTROL MEASURES

### SELECTING SEED FROM THE BIN

In order to insure a good stand of vines free from degeneration diseases, it is necessary to use as seed tubers that have come from healthy plants. Tubers affected with diseases like mosaic, leaf roll, and spindle tuber may appear entirely normal. One cannot determine, therefore, from an examination of tubers in a bin whether they came from a healthy parent; this can be ascertained only from an inspection of the growing plants. To obtain healthy seed it is necessary either to maintain selection in a seed plot year after year or to purchase seed from some one who does practice such selection. The method of maintaining a seed plot is described in detail on page 33. Some growers prefer to buy enough good seed each year to plant an increase plot from which they obtain sufficient seed for their main planting of the following year.

If seed stock is to be obtained from a bin, regardless of its previous performance or condition in respect to diseases, there is a possibility of eliminating some of the undesirable tubers by careful sorting. Ordinarily, small tubers should not be used for seed if one depends upon bin selection alone for obtaining it. It is true that a small tuber from a good-yielding healthy hill is as satisfactory for seed purposes as is a large tuber from the same hill and much better than a large tuber from a diseased vine. It also has been observed frequently that small tubers planted whole will give a better stand in years when conditions are unfavorable for germination than will larger cut tubers. Nevertheless, plants affected with wilt, black leg, and degeneration diseases, and plants lacking vigor for other reasons, usually have more small tubers than medium-sized or large ones. Consequently in selecting small tubers from a bin, the chances are great that many of them will come from diseased plants and will themselves produce diseased stock incapable of giving a satisfactory yield.

Tubers not typical of the variety represented should be rejected, as well as those that are much elongated or spindle shaped; those that have numerous eyes, eyes too shallow for the variety, eyes prominent or bulging; those that have knobs or warts; those that are irregular in shape or have an unnatural color; and those that have growth cracks. Such conditions often are the result of diseases like spindle tuber and yellow dwarf. It is true that tubers from healthy vines may grow irregularly and that such tubers will produce healthy plants, but the chances for avoiding diseases are better if only tubers typical of the variety are selected.

Tubers affected with rot should not be selected because the rot may continue to develop after the tuber is planted so that the sprouts grow poorly or not at all. In addition, if the rot is due to the late-blight

organism, a later infection of the vines may result in the field. Neither should tubers badly scabbed or severely affected with scurf be used, even though such tubers may produce a clean crop, for there is not only a probability that subsequent infection of the new crop may result from their use unless they are treated, but also that the sprouts may be weak or fail to develop.

While cutting the tubers those showing a decided stem-end browning, a netted brown discoloration, black-heart, or other internal discoloration, should be discarded, since they may develop weak sprouts and give poor stands. Tubers that are hard, when normal ones cut easily, should not be used for seed, as such hardness has been associated with leaf roll or other diseases.

It may be possible to sort out certain undesirable tubers by examining the developing sprouts. Tubers that have thin needle-like sprouts, commonly termed "spindling-sprout," should be discarded, since such sprouts indicate a lack of vigor in the tuber. This is true also of tubers that develop the first crop of sprouts from all or nearly all the eyes. Normal tubers will produce vigorous sprouts only from the eyes at the seed end, unless the tuber has been cut into pieces, in which case the eyes from each piece will grow. It has been recommended that tubers for the seed plot be sprouted by spreading them out in thin layers where they are exposed to a dim light and that, after sprouting has progressed sufficiently, they be sorted in order to remove all those lacking strong, vigorous sprouts at the seed end.

Seed growers who are uncertain of their own seed stock or of that which they have purchased may find it advantageous to know in advance of planting what percentage of disease is present. If the seed stock should show more than 8 or 10 per cent of disease, it probably will not be desirable to plant for seed purposes. It is possible to find the amount of infection by indexing the tubers as described on page 36, but a simpler method is to grow a fair sample, consisting of about 2 bushels or more, in some southern State where it can be planted early in the year. Within two months after planting, the vines will be large enough to show symptoms of most of the degeneration diseases and an inspection of them then will indicate the approximate percentage that will occur in the field when planted with the remainder of the stock. The inspection service of the College has for the past two years provided an opportunity for seed growers to have their stock tested in Florida at a minimum cost, and to obtain a report of the test in April. If a sample contains too high a percentage of disease to be satisfactory, it may be possible to replace it with stock of the same variety from some other grower whose sample indicated relative freedom from disease.

## SEED TREATMENT

### Disinfection

#### Purpose

Rhizoctonia and the scab organism, when existing on the surface of the tuber, can be destroyed by proper disinfection. This does not signify that by such treatment these diseases can be prevented from affecting the new crop, for the organisms causing them may be present in the soil and attack the new plants even if the seed is treated. Many experiments and demonstrations have shown that seed treatment often results in a cleaner crop than is obtained from untreated seed and that the yield is increased notably by this practice. Seed treatment has a marked effect in insuring a good stand by destroying the organisms on the surface of the tuber that cause rapid decay of the seed piece during hot weather and by destroying the sclerotia of Rhizoctonia which cause a rotting of the sprouts.

#### Time to treat

The treatment can be made safely at any time while the tubers are dormant. It usually is more convenient to treat in the spring just before planting, but in the fall before the potatoes are placed in storage it can be done without injury to the tuber or without material danger of recontamination. Tubers treated with corrosive sublimate in autumn should be stored where there is no chance of their becoming mixed with or mistaken for untreated tubers to be used for the table or to be fed to stock, as this material is poisonous. Treatment in the spring should be done preferably before the tubers have sprouted to any extent. Treatments made after the sprouts have become well developed may sometimes cause injury and retard germination. Late treatments, therefore, should be made ten days or two weeks in advance of planting. Potatoes having had the sprouts removed several times and those much shrunken are more subject to injury from treatment than are those in a dormant condition. The treatment should always be made before the tubers are cut for planting, as cut tubers are more easily injured by chemicals.

#### Materials

Either formaldehyde or corrosive sublimate (bichloride of mercury) may be used for disinfecting potato tubers. Corrosive sublimate appears to be more effective in the destruction of the sclerotia of Rhizoctonia and is the disinfectant usually employed in this State. Formaldehyde, however, is used ordinarily in the Middle West. It has the advantage of being much less poisonous to animals than is corrosive sublimate, of re-

taining its strength with successive treatments, of being free from corrosive action on metals, and of being a little cheaper. The vapor given off by it, however, is irritating to the nose and throat, especially when the hot treatment is used.

### Methods

There are two methods of treating seed—one known as the cold method and the other as the hot method.

#### Cold corrosive sublimate

For the average farmer, ordinary fifty-gallon barrels are the most accessible containers for holding the tubers during treatment. These should



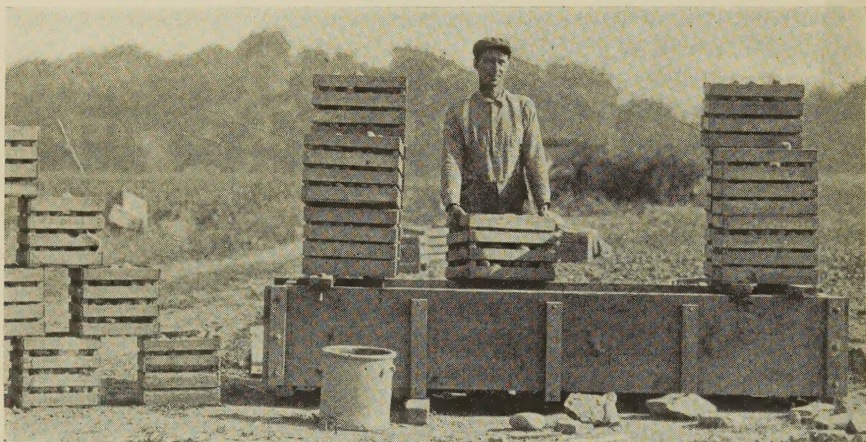
FIGURE 1. ARRANGEMENT OF BARRELS FOR TREATING SEED POTATOES

be reasonably clean. Oil barrels may be employed if scrubbed with soap and water. Planks are laid across two blocks of wood to make a platform as high as a pail. As many barrels as are needed, depending upon the quantity of potatoes to be treated and the number of men working, are set in a row upon this platform (figure 1). One barrel in which to mix the solution is left standing on the ground. A hole an inch in diameter is bored in the side near the bottom of each barrel on the platform for the removal of the solution after the seed treatment. These barrels, together with two pails, preferably wooden or enameled ware, a wooden paddle, a tea kettle for boiling water, and the glassware for testing the solution, are the apparatus needed for treating the seed.

Some growers prefer a wooden or cement trough large enough to accommodate 8 or 10 crates set side by side (figure 2) and high enough so that the solution will cover the tubers when the crates are filled. Other

devices have also been used. Each person should work out for himself the kind of apparatus most convenient and available under his conditions.

Metal containers and burlap or other bags should not be employed in soaking the seed, as corrosive sublimate reacts with these substances and becomes weakened by contact with them. Dirt also weakens the solution;



COURTESY OF DANIEL DEAN

FIGURE 2. TANK ARRANGEMENT FOR TREATING SEED POTATOES

thus, it is advisable to clean the containers before using them, and, if the tubers are covered with soil, to wash them before treating.

A suitable place for the apparatus should be selected, having in mind the location of the storage, the water supply, and the place where the tubers will be kept after treatment. As seed treatment is sloppy work, some place out-of-doors is desirable, unless the treatment is made on rainy or frosty days.

Corrosive sublimate is a fine, white, crystalline powder. The amount required to treat a given quantity of potatoes will vary with the number of tubers to be treated, the nature of the containers, and the amount of dirt on the tubers and in the containers. From  $1\frac{1}{2}$  to 2 pounds usually will treat 100 bushels. Four ounces of corrosive sublimate are necessary to make 30 gallons of a standard solution (1-1000). One may weigh it, himself, or have it put up in four-ounce packages when buying it. Some companies include with each pound package a ladle for measuring the required amounts. The four ounces of powder are dissolved in about a gallon of hot water in an earthen, glass, or wooden container. After every lump has been crushed with a paddle, or stirring rod, and no more remains undissolved, the hot solution is added to the 29 gallons of cold

water in the barrel on the ground, and then stirred with a paddle. Very cold water should not be used, as the corrosive sublimate is not active at low temperatures.

The first barrel on the raised platform should be nearly filled with potatoes, and the solution poured over them until the tubers at the top are covered an inch or more with the liquid. They are left in the solution for one and one-half hours. The exact time that the solution should be drawn off should be marked with a pencil on the barrel. An alarm clock has proved to be a good reminder. While the first barrel of tubers is being treated, the other barrels may be filled and more solution made to cover their contents. When the tubers have remained in the solution the sufficient length of time, the plug is removed and the solution caught in a pail as it comes out and dumped into the barrel on the ground. Two men with pails can easily take care of this. The last pailful of this solution may be discarded if it is very dirty. The barrel is then tipped over, the potatoes dumped on the ground or floor, and the barrel put back in place and again filled with untreated potatoes. After the used solution has been tested and restored to the proper strength by the addition of more corrosive sublimate, it may be used again. Each successive barrel is emptied after the proper lapse of time. With from 6 to 8 barrels in use, two or three men will be kept busy making the treatments. From 200 to 300 bushels can be treated in a day if the location of the treating apparatus, the water supply, and the storage are convenient.

An immersion as short as one-half hour has been advised for the seed treatment by some experiment stations. In our tests such short periods have not been effective in destroying the larger sclerotia of *Rhizoctonia*. Soaking the tubers overnight in water to soften the sclerotia has been said to make them more susceptible to the short-time treatment. This adds additional labor in handling the tubers. The same results may be obtained by spreading the potatoes on the ground, covering them with sacks, wetting them thoroughly, and leaving them covered overnight. A half-hour treatment after the wetting probably will destroy the *Rhizoctonia* on the tubers if the sclerotia are not large. Those trying this method should do so with the knowledge that it may not prove thoroughly effective.

After the solution has been used three or four times, it usually becomes one-half or less as strong as when freshly made. In order to have an unweakened solution, it has been a custom to discard it after the third treatment. A longer treatment with the second use than with the first and with the third than with the second, has been advised to offset this difference in strength. Others have recommended the addition of a small quantity of corrosive sublimate after each treatment, but this method is unsatisfactory because of the uncertainty of the strength of the solution thus

prepared and the necessity of discarding it after four or five applications. A better way is to determine the strength of the solution after each immersion and to add just enough corrosive sublimate to bring it to the proper strength. By this method the solution need not be discarded at all unless it becomes very roily.

**Testing the solution.** The apparatus needed for making the test consists of a quart bottle to hold the testing solution, a small bottle holding about two tablespoonsful for measuring this solution, a glass jar for mixing (a pint fruit jar or a large jelly glass will do), and a graduated glass cylinder of 100 cubic centimeters capacity for measuring the corrosive-sublimate solution. This may be obtained at a drug store, but one may use a tall narrow bottle of uniform diameter with marks filed on its side at quarter-inch intervals.

Five metric grams (about one-sixth ounce) of potassium-iodide crystals are dissolved in 1000 cc. (about 1 quart) of rain or distilled water to make the testing solution. It is not necessary to have a definite concentration but this strength (0.5 per cent) is convenient for checking. After the iodide is dissolved, 1 tablespoonful of copper sulfate <sup>solution</sup> (1 pound in 1 gallon of water) is added.

The first test is made after the corrosive-sublimate solution is made up and before any tubers are treated. Enough of the potassium-iodide solution is poured into the small bottle to fill it to the top. *The same amount of potassium-iodide solution must be used each time the test is made.* This is then poured into the mixing jar. The graduated cylinder, or the bottle, for measuring the corrosive-sublimate solution is filled to the top mark. This solution is then added very slowly to the potassium-iodide solution in the mixing jar, shaking the jar in the meantime, until a distinct orange color or precipitate forms. This coloration is known as the "end point." The quantity of corrosive sublimate necessary to produce the color is then recorded. The record should not be taken when the precipitate is first seen, for it disappears upon shaking the mixing jar; but on adding more corrosive-sublimate solution, it becomes permanent and distinct. It will require just two measures of a corrosive-sublimate solution of standard strength (1-1000) to reach the "end point" in one equal measure of a 0.5-per-cent potassium-iodide solution.

After the corrosive-sublimate solution has been used for the seed treatment, more water may be added to it, if necessary, to bring it to the original volume. It must then be tested again to determine how much additional corrosive sublimate should be added to bring the solution to standard strength. Again the same amount of potassium-iodide solution is added to the mixing jar, and the corrosive-sublimate solution added

until the precipitate is formed. Since the sublimate solution is weaker now, more will be required to form the orange-colored precipitate. The proportionately larger amount will indicate the quantity of corrosive sublimate that has been removed in the treating and the amount that must be added. For instance, if 2 parts, or measures, of the corrosive-sublimate solution were required to form the precipitate in the first test, and 3 parts, or measures, were required in the second, the solution is only two-thirds as strong as it was originally. Therefore, one-third of the original 4 ounces of the poison, or  $1\frac{1}{3}$  ounces, are to be added. In a similar manner, the proportion can be figured for any loss in strength that may have taken place during the seed treatment, and the amount of corrosive sublimate to add can be determined. Ordinarily, it is more convenient to dissolve 4 ounces of corrosive sublimate in one gallon of hot water and to measure such part of this as will correspond to the weight needed. After adding the poison to the weakened solution, it is a good policy, for a few times, to test the strengthened solution in order to verify the determinations. The entire process of testing is much more simple and more quickly done than a written description would lead one to believe. With a little practice, a test can be made in a minute or two.

After the solution becomes roily, the orange color of the precipitate may be lacking, but a decided precipitate, even if milky in color, may be taken as the "end point" instead of the orange color. In order to see this point clearly, it is advisable to have a pail of water in which the mixing jar may be washed after each test.

### Hot corrosive sublimate

The warmer the solution, the shorter will be the time required for treatment. When the solution is heated to from  $124^{\circ}$  to  $126^{\circ}$  F. by means of live steam from a boiler, the potatoes need be soaked for only two minutes. This saves much time as from 1000 to 2000 bushels can be treated in a day. A wooden tank holding from 8 to 10 crates set side by side and about 500 gallons of solution, is used for the purpose. It should have a false bottom which provides as much space below the crates as is occupied by them. This larger body of solution prevents much fluctuation in the temperature when a crate of potatoes is put in. By this method two men are kept busy putting in and taking out the filled crates. Another man is needed to take the temperature, to test the solution from time to time, and to dissolve and add more corrosive sublimate. A head of about 80 pounds of steam is needed to maintain the temperature in a tank of this size. The steam can be conducted into the tank by means of a rubber hose or by an iron pipe. A valve near the boiler regulates the supply of steam. It will require about one pound of corrosive sub-

limate for each 75 to 80 bushels of potatoes to be treated in the hot solution.

### **Cold formaldehyde**

These directions are given for those who prefer to use formaldehyde. In our tests it has not proved so effective as corrosive sublimate. One pint (1 pound) of 40-per-cent formaldehyde (formalin) is diluted in 30 gallons of water. The tubers are soaked in this for two hours, after which they are removed and dried. The same solution may be used over and over, for it does not lose strength quickly. The apparatus may be the same as that described under the cold corrosive-sublimate method, but metal containers may be employed, if desired, as formaldehyde does not corrode metal. A shorter immersion has been recommended by some experiment stations but it seems inadvisable in view of the slowness with which formaldehyde penetrates the sclerotia of *Rhizoctonia*. The pre-soaking already described followed by the period of an hour or two after treatment when the tubers are covered with bags to retain the moisture, may help to make a short-time treatment more effective.

### **Hot formaldehyde**

The treatment with formaldehyde can be hastened greatly by heating the solution as suggested for corrosive sublimate. Either metal or wooden tanks may be used in making the treatment. Two pints of 40-per-cent formaldehyde (formalin) are diluted with 30 gallons of water, making a solution twice as strong as is used in the cold treatment. This is heated to a temperature of from 118° to 122° F., and held within these limits by means of live steam, as described under the hot corrosive-sublimate method, or, when a metal tank is used, by means of a fire maintained in a trench beneath the tank. In the latter case the temperature of the solution is controlled by regulating the draft, and, if the temperature starts to run high, by the addition of a cold solution of the same strength. When a fire is used beneath the tank, a false bottom should be put in the tank to keep the tubers at the bottom from becoming overheated.

The potatoes in wire baskets or crates are immersed in the hot solution for two minutes. Bags may be used for the immersion but they do not permit the circulation of the hot solution among the tubers as well as do more open containers. When steam is employed for heating, it is necessary after each 50 bushels of potatoes are treated to add 0.9 pint of formaldehyde and sufficient water to bring the solution to its former level. A good dairy thermometer is used frequently to determine the temperature which should not be allowed to fluctuate beyond the limits indicated.

After immersion, the tubers are placed in a pile and covered with bags, blankets, or canvas for an hour to hold the formaldehyde around them. Then, the covering is removed and the potatoes permitted to dry.

#### **Drying the tubers**

After the treatment is completed, the tubers are placed where they will dry out rapidly. They may be spread on the ground but must not be left where they will become overheated, as will occur when exposed to the hot sun even if they are covered with canvas, or other material, without an air space of a foot or more above them. They may be left in stacked crates so that a good circulation of air is available or they may be spread on the floor of the barn or other building.

#### **Injury from treatment**

Care must always be taken that seed-treatment injury does not occur from failure to carry out the directions given. Some lots or even in-

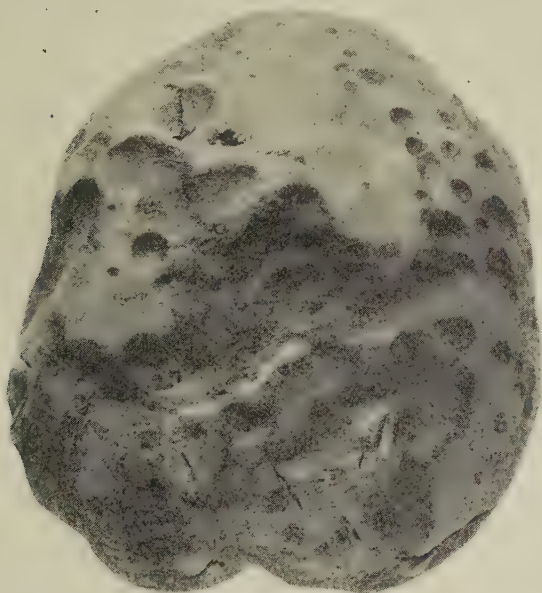


**FIGURE 3. SEED-TREATMENT INJURY**  
This injury causes sunken brown spots on the tuber

dividual tubers are more susceptible to injury from treatment than are others. A dormant tuber is less likely to be injured than one that has sprouted considerably. An injury that has been observed to follow treatment is the occurrence of sunken areas, or pits, around the lenticels. The flesh in these pitted areas is discolored (figure 3). This may be produced by a long period of immersion in a solution stronger than recommended or by failure of the surface of the tubers to dry rapidly enough after the treatment is completed. Any one of these conditions may cause the death of the sprouts. But no injuries need occur if care is taken to treat the potatoes before they sprout and become withered, to keep within the limits of time for immersion and subsequent covering, and to maintain the strength and the temperature of the solution as prescribed.

### Greening, or sprouting, seed tubers

The only excuse for discussing in this bulletin the greening, or sprouting, of tubers is because of its relation to disease control.

Sprouting the tubers in a dim light either by spreading them out in shallow layers or by placing them in loosely stacked crates for a period of two or three weeks enables one to detect from the appearance of the sprout what tubers are undesirable for seed. Since the tuber is cleaner after treatment in a solution, it is possible to detect more easily the blemishes that disqualify it for seed purposes. The kind of tuber to be discarded has already been described on page 4.

Whatever practice hastens the appearance of the sprouts after the tubers are planted will usually aid in increasing the percentage of stand in the field. Failure of the sprouts to appear, their delay in appearance, or their emergence as weak plants, generally is due either to the rapid decay of the seed tuber or to the formation of *Rhizoctonia* cankers on the sprouts. If strong, stocky, green sprouts are already formed when the tubers are planted, they have a better chance of appearing above ground and of establishing their roots in contact with soil nutrients than if the seed tuber had developed spindling sprouts. Whether the practice of greening would pay New York potato growers every year cannot be stated, but observations made in years when conditions in the field were unfavorable for rapid growth immediately after planting clearly demonstrate its value. The actual cost of greening should not be great. The greatest drawback on most farms is the lack of space.

Greening can be accomplished by spreading the potatoes out in thin layers where they can be exposed to some light. Intense light is unnecessary and high temperatures are undesirable as black-heart may develop. For this reason tubers ordinarily should not be exposed to the direct rays

of the sun. The floor of a barn or other building with windows is satisfactory. They may be spread on the ground if shade is provided and the temperature does not rise much above 80° F. Under such conditions a number of thick, stocky, green sprouts will be formed at each seed-end eye. A very short green sprout will be formed in the eyes of the stem-end if the tuber is not cut, but, if the tuber is greened after cutting, sprouts similar to those at the seed-end will be formed at the other eyes as well.

### CUTTING THE SEED

Many growers prefer to cut the seed just before planting; others, particularly those on Long Island, find it necessary to cut some time in advance. The objection of up-state growers to early cutting is that the seed is more likely to rot and to give poor stands. The rotting is due to bacteria that develop very rapidly when the temperature is high. Cutting and planting on Long Island is done early in the season when the prevailing temperature is relatively low, which explains why rot does not result there from early cutting. Treating the seed destroys the bacteria on the surface of the seed tuber, so that treated seed cut early will not decay as readily as will early-cut untreated seed. Even when treated seed is cut early, it should be placed in crates or spread out in order to provide good ventilation. Dusting the cut seed with gypsum or sulfur prevents cut surfaces from adhering to each other. If cut seed is kept under these conditions, the cut surface heals over and the seed will be as free from rot before and after planting as is uncut seed. In fact, cut seed properly healed over and whole seed may endure unfavorable growing conditions following planting and will then produce a good stand when seed cut just before planting will decay and give a poor stand.

The person cutting seed has a good opportunity to detect and to discard all tubers having internal discolorations or other defects as mentioned on page 5. Ordinarily, it is not necessary to disinfect the cutting knife during its use, as infection from most potato-disease organisms, or agencies, will not result even when these organisms are present. However, in the case of black leg and bacterial brown rot, two bacterial diseases not very common in the State, and in the case of spindle tuber, infection may take place from the use of a contaminated cutting knife. If tubers affected with any of these diseases are encountered, the knife should be placed for ten or fifteen minutes in a dish containing a solution made of one tablespoonful of formaldehyde and one-half pint of water.

### APPLICATION OF CHEMICALS TO THE SOIL TO PREVENT SCAB

The application of chemicals to the soil to prevent scab is discussed on page 94.

### SOIL TEMPERATURE AT PLANTING TIME

When the soil temperature goes above 80° F., it is wise to delay planting until a rain or a cool air temperature lowers it. Tubers planted at high soil temperatures, especially untreated and freshly cut tubers, are subject to decay and to poor sprout growth which results in a poor stand and many weak plants. High soil temperatures can be controlled to some extent by early plowing and frequent cultivation, for these practices favor the retention of moisture. The temperature of the soil of late-plowed fields and of soil that naturally is coarse or lumpy after tilling is raised easily during periods of high air temperatures, especially if the weather has been dry.

### ROTATION

A rotation of crops in which potatoes are planted every three or more years is generally considered helpful in reducing the attack of soil organisms as *Rhizoctonia* and those causing scabs and wilts. In the absence of a host plant it is supposed that these organisms become less virulent or that their number decreases. However, rotations alone are not sufficient; other practices outlined in this bulletin are also important. Rotation may well be employed as one step in the control, especially as the practice is desirable for cultural reasons. On the other hand, it is a common practice on Long Island to grow potatoes for many years in succession in the same field. Apparently there has been no greater trouble there from soil organisms causing disease than in up-state potato regions where a rotation is the general practice. This should not be interpreted to mean that rotation is not of value as a means of disease control in up-state counties.

### LOCATION OF FIELD FOR SEED POTATOES

The seed grower should give very careful consideration to the location of his field in respect to other potato fields, but this is not so necessary to the grower of table stock unless he expects to use some of the crop for seed. If fields are planted to good stock so that they remain relatively free from degeneration diseases, there is no objection to having them adjoin a seed field; but, if they are affected with diseases to any considerable extent, there is a strong probability that many plants on the adjoining side of the seed field will become affected. Even though they remain apparently healthy during the season, exposed plants will produce tubers all or many of which will be affected and which will produce affected plants the following year. The extent of the infection depends on the percentages of affected plants present in the adjoining field, the proximity of the field, the abundance of insect-carriers, the location of the

two fields in respect to the possibility of the insects being carried by wind from the affected field to the other, and on other circumstances. It is, therefore, impossible to say how far from a diseased field one should locate a field for seed potatoes. Some evidence seems to indicate that it should be at least from 200 to 300 feet distant; and, of course, the greater the distance, the less the liability to infection from such a source.

It has been proved repeatedly that potato aphids are able to transmit degeneration diseases from affected to healthy plants. In Maine, it was found that the green and rosy aphid is the kind most common on potato vines and that this species winters as eggs only on rose bushes. It was also observed that potato vines in the vicinity of rose bushes are the first to become infested with aphids, and that, as they increase in number, they spread to other parts of the field. Consequently, it was recommended that rose bushes within a radius of a mile from potato fields be destroyed or, if valuable, be sprayed with a nicotine-sulfate solution to kill the newly-hatched aphids. Whether this is necessary under New York conditions, it is impossible to say, for sufficient observations have not been made to warrant a recommendation. Aphids were observed in many fields in 1925 and a further search may prove them to be more widely distributed in potato fields of the State than has been believed heretofore.

### ROGUING

It is necessary for the seed grower to remove undesirable plants. This is known as "roguing." Growers of table stock who do not use any of their potatoes for seed need not consider this method of eradication. The undesirable plants include those affected with mosaic, leaf roll, yellow dwarf, spindle tuber, wilt, black leg, "giant hills," and weak hills. Plants that are small, due to some accident, are not necessarily weak and need not be removed. The first three diseases mentioned can usually be detected by the time or before the plants have bloomed, but most of the others are not easily determined until later and some are often difficult to determine at all. During hot weather, the mottled symptoms of mosaic are usually lacking, that is, "masked," so that this disease is then much more difficult to detect. The vine characters of spindle tuber on some varieties are often difficult to distinguish from those of healthy plants, but the elongated tubers serve to indicate the disease.

The object of roguing is to remove diseased plants before the disease can be communicated to the healthy adjoining plants and to prevent the tubers of affected plants from being harvested with the healthy ones and used as seed. If the seed field is located some distance from any field affected with degeneration diseases and if the seed stock is healthy, it may

not be necessary to rogue. Usually the seed stock will have some infection and roguing must be done if the stock is to become suitable for seed. Two roguings often are necessary if the field is to pass inspection, that is, to qualify according to the potato standard adopted for certified seed. One of these is made about blooming time because certain diseases and varietal mixtures can readily be detected then, and one is made later in the season but before the vines begin to die. Maintaining a seed plot, as described on page 33, materially aids in reducing the amount of roguing necessary in the main field.

In removing an undesirable plant the seed piece and all new tubers sufficiently large to be used for seed are taken up with the vine. If the old seed tuber is left in the ground or even on the surface, it may send up new sprouts which are as much a source of danger as are the ones first produced. New tubers large enough for seed are likely to be picked up at harvest and included with the healthy ones. The rogued vines and tubers are removed from the field and buried or otherwise destroyed, or are scattered so far away that aphids and leaf hoppers present on them cannot make their way back. If such plants are left between the rows or on the ground at the border of the field and rains follow, they will remain alive for a long time or even continue their growth and serve as a source of contamination to healthy plants. If the weather permits the plants to wilt and die, any aphids and leaf hoppers present will migrate to adjoining plants and may thus transmit the disease.

The person roguing walks between two rows and upon detecting an undesirable plant pulls it carefully from the soil so that the seed piece is removed if possible. If the seed piece remains, it should be dug up. New tubers large enough for seed are also collected. Vines and tubers are placed in a bag carried by the roguer. Care is taken that aphids and hoppers, if present, are not brushed off. As these insects approach maturity they are very active and will usually get away while the plants are being pulled. It is for this reason that early roguing, when the insects are young or before they appear, is important. Burlap bags are scattered along one end of the field and as soon as one is filled, or heavy enough to be uncomfortable to carry, another is used. The filled bags are left at the end of the field until roguing for the day or half day is completed. It has been recommended that the roguer carry a 16-quart pail of kerosene emulsion, that is, one cup of kerosene is added for each five gallons of soap suds used. As soon as the vines are pulled, they are dipped in the suds and wrung out with the hands; they may be left on the ground between the rows since any aphids and hoppers on the vines are killed. This does not, however, obviate the necessity of remov-

ing the affected tubers from the field nor is it certain that the treated plant will die if left on the ground.

Ordinarily, two rows are all that one person can rogue at a time, but, if the percentage of undesirable plants is very low, it may be possible to rogue four rows satisfactorily. Mosaic can be detected more readily on a cloudy day than when the sun is shining. On bright days it is sometimes necessary to shade the plant in order to identify this disease with certainty. Roguing should be made before an application of spray or dust and not soon after, because fungicides obscure to some extent the symptoms of mosaic and even of other diseases. As is true with other work, practice is necessary before efficiency is assured. The assistance of some person familiar with roguing is very desirable when one starts to rogue for the first time. With practice an alert person can become very adept. Some potato growers are fully as keen in detecting diseases as is a trained pathologist.

#### APPLICATION OF A FUNGICIDE TO THE VINES

An application of a fungicide to the vines will keep them in a healthy condition so that they will produce a larger crop of tubers free from late-blight rot. The control of late blight is not the only result of this practice, for, even in years when the blight is absent, higher yields have been obtained from fields that have been sprayed or dusted than from those to which no fungicide has been applied (figure 4). This is due, in part

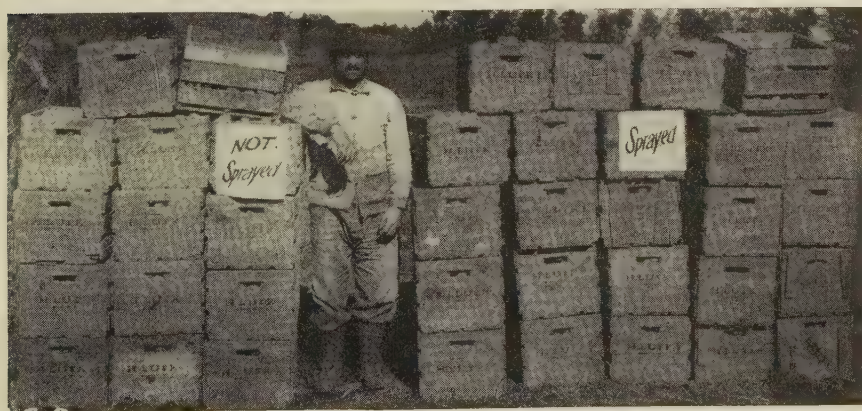


FIGURE 4. THE RESULTS OF SPRAYING

at least, to the protection afforded against tipburn, hopper burn, early blight, potato beetles, and flea beetles. A secondary effect is the better quality of tubers from vines protected with a copper fungicide.

## Spraying

Careful experiments, as well as numerous demonstrations, conducted for many years in this and in other States have proved amply that proper spraying with bordeaux mixture will give increases in yield that will not only pay for the cost of the practice but will give a profit which some years is considerable. This statement holds true in general in all potato-growing sections of the State,—in the northern section as well as in the southern, and on hillsides as well as in valleys.

## Materials

Bordeaux mixture, the material that has been used for many years as a fungicide for potatoes, is still the most satisfactory. A number of other fungicides containing copper have been prepared but none of them have proved to be as effective a fungicidal agent as is bordeaux mixture. Various proprietary bordeaux preparations have been or still are on the market. In comparative tests on potatoes, they have rarely proved to be as valuable for protective purposes as is homemade bordeaux mixture. Lime-sulfur should not be used for spraying potato vines, for it stunts their growth and results in reduced yields.

Bordeaux mixture is a precipitate obtained by mixing a solution of copper sulfate (blue vitriol) with a solution of lime. Copper sulfate ordinarily is in the form of blue crystals of various sizes but is also available in a granulated form. The latter is quite as satisfactory for making bordeaux mixture as are the crystals or even more so, for it dissolves more readily. When copper sulfate stands for a time in a dry place, it loses some of its water of crystallization and becomes white. This does not injure it, but the white form contains a higher percentage of copper than does the blue crystalline form. Under ordinary conditions this change does not proceed far enough to require adjustments in calculating the amount to use.

Lump lime, or burnt limestone, containing a high percentage of calcium oxide makes the best bordeaux mixture. A magnesium lime generally is considered much less satisfactory. Air-slaked lime should not be used and for this reason the lime should be as fresh as can be obtained. Hydrated lime, if fresh, may be used if lump lime cannot be obtained, but bordeaux mixture made of it does not remain in suspension as long as does that made from lump lime. Of the various hydrated limes, the form known as "finishing lime" is considered best for this purpose.

## Homemade bordeaux mixtures

**Preparation of the stock vitriol.**—When one has much spraying to do, the best way to prepare bordeaux mixture is to make a stock solution of

blue vitriol and one of lime. To make a stock solution of the blue vitriol, 1 pound of the crystals or grains is weighed out for each gallon of water. Approximately 1 gallon of this stock will then be equivalent to 1 pound of copper sulfate. It is true that 2 pounds of vitriol will dissolve in 1 gallon of water, in which case 1 gallon of stock solution will be equivalent to 2 pounds of copper sulfate, but mistakes are less likely to be made when 1 gallon of stock contains 1 pound of vitriol. If a barrel is used to hold the solution, 40 or 45 pounds of vitriol are placed in a clean burlap sack and suspended from the top of the barrel into which is poured as many gallons of water as there are pounds of vitriol. The warmer the water, the more rapidly will the vitriol dissolve; but it will dissolve in moderately cold water in the course of five or six hours. This solution should not come in contact with iron and for this reason barrels without nails or iron hoops are desirable. When a smaller quantity of stock is desired, the stock solution may be kept in an earthenware jar. The receptacle containing this solution is covered tightly to prevent rapid evaporation of its contents, and to keep out foreign matter.

**Preparation of the stock lime.**—A stock solution of lime is prepared by slaking from 40 to 50 pounds of good burnt lime in a barrel. In slaking the lime, the water is added slowly at first so that the lime is not drowned. There is a considerable difference in the slaking qualities of different limes. However, the use of hot water hastens the slaking and gives a smoother paste. While the lime is slaking, the material is stirred to a smooth paste. More water is added until there are as many gallons as there were pounds of lime slaked. The material is then stirred thoroughly to form a milk of lime and the receptacle covered. Inasmuch as the lime settles after standing for a time, the mixture should be stirred each time to a milk of lime before using.

If hydrated lime is employed for making bordeaux mixture, a stock solution may be prepared by adding water and then stirring the material. It will require about  $1\frac{1}{3}$  pounds for each gallon of water, for hydrated lime contains the equivalent of less oxide by weight than does lump lime.

**Preparation of the bordeaux mixture.**—It is more convenient to prepare the stock solutions near the water supply (figure 5). After they are made they may be kept as long as desired without danger of deterioration if water lost by evaporation is replaced. In order to know how much to replace, a mark may be made on the side of the receptacle to indicate the height of the solution when it was first made. The stock solutions are stirred thoroughly just before using them.

In preparing bordeaux mixture, the spray tank or other container is filled about three-fourths full of water. Then, the required amount of

stock solution of vitriol is added and the solution in the tank stirred. If a 5-5-50 bordeaux mixture is desired, 5 gallons of the stock solution of vitriol will be required for each 50 gallons of mixture to be made. Thus, if the sprayer or tank holds 100 gallons, then 10 gallons of stock will be



FIGURE 5. A HANDY APPARATUS FOR MAKING BORDEAUX' MIXTURE

required. If a 4-4-50 bordeaux mixture is desired, it will take 4 gallons of stock for each 50 gallons of mixture.

After the stock vitriol has been well mixed with the water in the tank, the stock lime is added. Since there are some coarse particles in the lime water, it is necessary to run this through a strainer as it is added to the solution in the tank. A copper or bronze wire strainer with eighteen meshes to the inch is best for this purpose, although several thicknesses of cheesecloth or other similar fabric may be used. The strainer is fastened to a frame which fits into the opening of the sprayer tank. As the stock lime water is added, the mixture in the tank is stirred vigorously. The resulting bordeaux mixture should be sky-blue in color. The amount of stock lime to use is the same as the amount of stock vitriol. Some growers prefer to test the bordeaux mixture while it is being made, adding enough

stock lime solution to neutralize the vitriol used. This may be done whether burnt or hydrated lime is used in the preparation.

**Different ways of preparing bordeaux mixture.**— There are several different ways of mixing the solutions of blue vitriol and of lime to make bordeaux mixture. The most practicable and satisfactory way is to dilute the required amount of stock vitriol in the spray tank and add the necessary amount of milk of lime to it, as already described. The resulting sky-blue mixture consists of thin gelatinous membranes which will remain suspended in the water for a long time. If the two stock solutions are mixed before either are diluted, the resulting precipitate is so coarse and heavy that it settles rapidly in the water that subsequently is added. A bordeaux mixture whose precipitate remains longest in suspension is made by adding diluted vitriol solution to the milk of lime of the stock solution, but to prepare such a mixture requires one large tank for the diluted vitriol besides the one holding the mixture. The slightly increased value of such a mixture does not warrant the expense of the necessary apparatus.

Other ways of mixing the materials to make a satisfactory bordeaux mixture are: (1) adding a dilute solution of lime to a dilute solution of vitriol, (2) a dilute solution of vitriol to a dilute solution of lime, (3) a dilute solution of lime to a strong solution of vitriol, or (4) pouring together a dilute solution of vitriol and a dilute solution of lime. If hydrated lime is used, the required amount of lime for a tank full of mixture may be weighed, placed in the sieve, and washed through with water until the tank is nearly full, after which a strong solution of vitriol is added. One grower has devised a plan by which water is run in equal quantities into two receptacles one of which holds enough granulated copper sulfate and the other enough hydrated lime to make the required strength of bordeaux mixture for a tank full of material. These receptacles have screened outlets with spouts conducting the solutions to the spray tank. As the water runs through these receptacles, the material within is gradually dissolved and carried as dilute solutions into the tank where they are thoroughly stirred as they come together.

No matter which way the bordeaux mixture is made, it is important that the correct amount of the materials is used and that their solutions are mixed in a manner to give a thin gelatinous precipitate that will stay in suspension. One easily can test the quality of a mixture by filling a quart glass fruit jar with it and allowing it to stand overnight. If the precipitate has settled so that more than two inches of clear liquid remains at the top, the mixture has not been made properly.

**Testing bordeaux mixture.**—The material for making the test is a solution of potassium ferrocyanide (yellow prussiate of potash). This is

a yellow, waxy, crystalline substance, a quantity of which, sufficient for the season, may be purchased at a drug store for ten or fifteen cents. This is placed in a half-pint bottle and covered with rain or distilled water. A V-shaped cut is made along the side of the cork stopper which is then forced tightly into the neck of the bottle. A few drops of the solution may be obtained by shaking them out.

After adding approximately the required amount of stock solution of lime to the weak vitrol solution in the tank and stirring thoroughly, some of it is dipped out with a saucer or other shallow earthenware receptacle and a few drops of the testing solution shaken in. If there is not enough lime present in the bordeaux mixture, a rusty brown precipitate will be formed wherever the testing solution comes into contact with it. One may become familiar with this color by testing before much lime is added. More stock lime is then poured in and stirred. When enough lime is present, the testing solution will not give the rusty brown reaction but will continue to have its pale-yellow color. As the test can be made quickly and easily, it is more convenient to use it than to weigh out the lime or to measure the lime solution. It is safer, however, to use some excess of stock lime than to use just enough to prevent the reaction with the testing solution.

**Preservation.**—Ordinarily no more mixture should be made than can be used at once. If, for some reason, it is impossible during the day to use up what has been made, the remainder may be kept from deteriorating for a few days by the addition of a tablespoonful of granulated sugar dissolved in a little water to each 50 gallons of a 5-5-50 bordeaux mixture. Much more sugar should not be used as it may be harmful. When bordeaux mixture is made with hydrated lime, the use of sugar at this rate also is helpful in retarding the settling of the precipitate and in preventing the reversion of the copper in the mixture to copper sulfate.

**Addition of poison to bordeaux mixture.**—When potato beetles are present, the addition of a poison to bordeaux mixture is necessary if spraying is to be effective against them. One pound of paris green or  $1\frac{1}{2}$  pounds of powdered arsenate of lead to 50 gallons of bordeaux mixture is sufficient if applied when the slugs are first hatched. As they grow larger it takes more poison to kill them. Paris green used alone with water often burns the foliage of potatoes, but, when used with bordeaux mixture, no such burning occurs. The use of a contact insecticide for the control of aphids has not yet proved profitable as a general practice.

**Cleaning out the sprayer.**—With the best made bordeaux mixture there is sure to be some sediment. When through spraying each day the nozzles should be removed and cleaned in water, the sprayer tank washed out, and water pumped through the pipe and hose in order to flush them.

This practice will help greatly toward preventing exasperating delays in cleaning nozzles the next time the sprayer is used.

### Prepared bordeaux mixture

It has already been indicated that proprietary bordeaux preparations in comparative tests rarely have proved to be equal to homemade bordeaux mixture as a protective application to potato vines. Their relative effectiveness depends upon the percentage of copper present, their ability to stay in suspension in water, and their adhesiveness.

The percentage of copper present is stated on the label. From this one is able to determine how many pounds of the material are needed to make a spray material equivalent in copper sulfate to that in a standard bordeaux mixture. For example, if a prepared bordeaux paste or powder contains 15.5 per cent metallic copper, or its equivalent, then the material contains an equivalent of copper sulfate equal to  $15.5 \times 3.93$  (a factor determined for the purpose) or 60.9 per cent. That is to say, 1 pound of the prepared bordeaux mixture contains 0.609 pounds of copper sulfate. To make a spray equivalent in copper to a 5-5-50 bordeaux mixture it will require as many pounds of the material as 0.609 is contained in 5, or approximately 8.2 pounds for each 50 gallons of water. For the convenience of those desiring a prepared bordeaux mixture, the following table will be useful in determining the amount of material needed to make a spray equivalent in copper to that of a homemade bordeaux mixture.

TABLE 1. POUNDS OF A CONCENTRATED MIXTURE NECESSARY TO MAKE A SPRAY EQUIVALENT IN COPPER CONTENT TO A HOMEMADE BORDEAUX MIXTURE

| Metallic copper declared on label<br>(per cent) | Equiva-<br>lent of<br>copper<br>sulphate<br>(per cent) | Pounds of concentrated mixture<br>necessary to add to 50 gallons<br>of water to make a bordeaux<br>mixture of the following formula |        |        |
|-------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|--------|--------|
|                                                 |                                                        | 3-3-50                                                                                                                              | 4-4-50 | 5-5-50 |
| 1.5.....                                        | 5.89                                                   | 50.9                                                                                                                                | 67.8   | 84.8   |
| 2.....                                          | 7.86                                                   | 38.1                                                                                                                                | 50.8   | 63.6   |
| 2.5.....                                        | 9.82                                                   | 30.5                                                                                                                                | 40.7   | 50.9   |
| 3.....                                          | 11.79                                                  | 25.4                                                                                                                                | 33.9   | 42.4   |
| 3.5.....                                        | 13.75                                                  | 21.8                                                                                                                                | 29.0   | 36.3   |
| 4.....                                          | 15.72                                                  | 19.0                                                                                                                                | 25.4   | 31.8   |
| 4.5.....                                        | 17.68                                                  | 16.9                                                                                                                                | 22.6   | 28.2   |
| 5.....                                          | 19.65                                                  | 15.2                                                                                                                                | 20.3   | 25.4   |
| 6.....                                          | 23.58                                                  | 12.7                                                                                                                                | 16.9   | 21.2   |
| 7.....                                          | 27.51                                                  | 10.9                                                                                                                                | 14.5   | 18.1   |
| 8.....                                          | 31.44                                                  | 9.5                                                                                                                                 | 12.7   | 15.9   |
| 9.....                                          | 35.37                                                  | 8.4                                                                                                                                 | 11.3   | 14.1   |
| 10.....                                         | 39.30                                                  | 7.6                                                                                                                                 | 10.1   | 12.7   |
| 11.....                                         | 43.23                                                  | 6.9                                                                                                                                 | 9.2    | 11.5   |
| 12.....                                         | 47.16                                                  | 6.3                                                                                                                                 | 8.4    | 10.6   |

Prepared bordeaux mixture may be had with or without an arsenical poison. The arsenical bordeaux mixtures necessarily are more expensive than those containing no arsenical. When the percentage of metallic copper present is low in an arsenical bordeaux, more poison must be used than is needed in preparing a spray that will be equivalent in copper sulfate to a standard bordeaux spray mixture, as a 5-5-50. For this reason a prepared arsenical bordeaux with a high copper content is desirable because it will be cheaper to use than one containing a low percentage of copper.

### **Application of the spray**

#### **Time and number of applications**

To do effective work and to obtain the highest returns, the spraying must be started when the vines are from 4 to 6 inches high and continued at regular intervals throughout the growing season of the vines. The number of applications necessary depends considerably upon the weather during the season, the location of the field in respect to exposure to winds, and to the prevalence of flea beetles and leaf hoppers. If these insects are abundant early in the season or if the summer is rainy and thus favoring the development of late blight, several more applications are necessary than if these factors were not present or were unimportant. Bordeaux mixture has been reported to stimulate growth and consequently to increase the yield, so that more applications may be advisable than the control of pests and diseases would seem to require during years when these are not troublesome. Mistakes are more often made by spraying too few rather than too many times. During some years and in some localities five or six applications are sufficient, while under other conditions from ten to twelve applications are none too many. It is a good policy to keep all new growth protected with the fungicide and to renew the application on the older growth.

#### **Amount of material to use**

In order to give a good protective coating to the vines, it will require for each application from 60 to 75 gallons of the mixture to an acre when the plants are small and from 100 to 125 gallons when the plants are full grown, depending on the variety.

#### **Thoroughness**

It is essential that the vines, including the upper and lower surface of leaves, be covered thoroughly to give sufficient protection during seasons when the weather is favorable for extensive development of late blight or when leaf hoppers or flea beetles are numerous. One nozzle to a row is

sufficient if the vines are small; but, ordinarily, it will require two or three nozzles if the vines are large. When one nozzle to a row is used, it is attached so that the spray is directed downward; when two nozzles are used, they are attached to long nipples to direct the spray on both sides of the plant in order to cover the lower as well as upper surface of the vines. When three nozzles are used, they are attached so that one shoots the spray downward; the other two direct the spray upward and to the sides of the plant. It is important that all surfaces of the vines and leaves receive a uniform coating with the spray. One may determine whether this is done by inspecting the vines after the mixture has dried on them, as it will do within a short time. If the distribution is not satisfactory, the nozzles should be adjusted. Nozzles placed close to the vines will give unsatisfactory distribution, because some leaves will receive too much spray and injury is likely to occur from the forceful contact of the spray material. A little experimenting will enable one to decide upon the proper adjustment of the nozzles as regards the distance from the plant and the angle at which the spray may be directed to give a uniform covering.



FIGURE 6. A FOG OF SPRAY ENVELOPING THE PLANTS

The spray should reach the vines as a fine mist (figure 6). The pressure at which the spray mixture is forced from the nozzles and the size of the aperture are conditions influencing the fineness. The greater the pressure

and the smaller the aperture, the finer will be the spray. The larger the opening in the nozzle, the higher the pressure needed to produce a finely divided spray. A large opening and a high pressure, however, may deliver a greater quantity of material than needed during a given interval of time. All these factors must be given consideration in deciding on the number of nozzles to use. When either two or three nozzles to a row are used, the spraying machine should maintain sufficient pressure, registered on the air chamber, to deliver from 100 to 125 gallons of spray material to an acre in the form of a finely divided spray. A pressure of from 150 to 200 pounds will be needed to accomplish this.

### **The spraying machine**

A spraying machine should be durable and, in addition to the qualifications already mentioned, it should be constructed so that its working parts will readily be accessible, particularly the pump valves, and the opening into the tank should be large enough to permit one to reach the agitator when necessary for adjustment or for repair. The machine should have a safety valve, a device to hold the pressure while the machine is being turned around at the end of the rows, and it should have a thimble strainer for the nozzles. It is important that parts of the machine can readily be obtained from near-by points, otherwise one may be forced to delay applications at critical times when some part breaks.

The size and the kind of machine to use will depend upon the area to be sprayed. If one has less than three or four acres, it may not pay to buy a traction sprayer. A homemade sprayer with an attached hand pump may be constructed or a wheelbarrow sprayer may be purchased that will meet requirements. Such machines usually do not deliver enough material at one application to give effective protection. A number of growers having small acreages in the same neighborhood may form a spraying association and arrange to have their spraying done with a large machine. Such an arrangement will usually give better protection to the potatoes than when a small machine is used. On small acreages, however, a hand dusting machine will be found satisfactory as it will require less labor to operate than a spraying machine. For larger areas, a traction or power machine will be necessary.

**A vine spreader.**—Spraying machines are rarely, if ever, provided by the manufacturer with a vine spreader. This is useful in preventing the vines from being injured by the wheels of the machine while spraying when the plants are large. Daniel Dean of Nichols, New York, has devised and used for years a satisfactory vine protector which may be constructed for use on any wheeled machine. It consists of four  $\frac{1}{2}$ -inch rake teeth, one for each side of each wheel, attached to a 2x4-inch hardwood cross-

piece which is fastened by hinges beneath the frame of the machine. This contrivance is set far enough forward so that the rake teeth will pull the vines away from the wheels. A lever, attached to the crosspiece between a wheel and the tank, enables one to raise the teeth while turning at the end of the rows or while on the road.

### Dusting

In recent years, dusting has come into practice as a substitute for spraying potatoes. The right material properly applied has been effective in controlling late blight. However, dusting does not appear to be as effective as is bordeaux spray in the control of leaf hoppers and flea beetles and is somewhat more expensive at the present time. As no water is needed, the loaded dusting machine is lighter and easier to operate than is a sprayer. A larger acreage can be covered in a day, and the machine can be operated in fields where a sprayer could not be taken. There are fewer delays in operating a duster than is true of a sprayer, since there is no trouble with clogged nozzles or bursted hose. A duster is practicable where a water supply is not available, for hilly fields where a sprayer cannot operate, for large areas where one wishes to economize labor, and for areas too small to permit an investment in a traction sprayer.

### Materials

The most satisfactory dust for spraying potatoes is a mixture of monohydrated copper sulfate and hydrated lime with powdered lead arsenate or calcium arsenate added when an arsenical poison is necessary. The materials must be fine enough so that 95 per cent of each ingredient or of the mixture will pass through a 200-mesh sieve. Proprietary bordeaux dust mixtures, prepared by drying a bordeaux mixture, have proved to be less effective than the copper-lime dust.

Various percentages (from 15 to 25) of the copper sulfate have been used in the dust mixture but 20 per cent may be considered as a satisfactory amount. When no arsenical is present, this is expressed as a 20-80 copper-lime dust. When an arsenical is needed, either lead arsenate, from 7 to 15 per cent, or calcium arsenate, from 10 to 25 per cent, replaces an equal percentage of the lime. If 10 per cent lead arsenate were used in the mixture, it would be expressed as a 20-10-70 copper-arsenate-lime mixture. Calcium arsenate is cheaper than lead arsenate and, although more likely to cause injury to the foliage of tender plants, usually is safe to use on potato vines. From 10 to 15 pounds in 100 pounds of mixture are sufficient for the control of the potato beetle.

The dust may be purchased already mixed, or one may purchase the ingredients separately and mix them himself. The materials are cheaper when purchased unmixed, but, unless one has a good mixing machine, it

is advisable to buy the mixture. Machines can be purchased or a satisfactory one can readily be constructed. Some are so made that the dust may be mixed in the hopper when desired. A mounted revolving barrel, supplied either with baffle boards attached to the inner sides or with round cobblestones placed within to stir up the mixture, may be used as a mixing machine. Revolving barrel churns have been used for the purpose. Since the mixture deteriorates on long exposure to the air, it should be made up as needed or kept in air-tight containers.

#### Application of the dust

##### Amount

The amount of dust to use, when properly applied, depends upon the size of the plants and the percentage of copper present in the dust. One should endeavor to apply enough dust to the acre so that the amount of copper will be equivalent to that used if a bordeaux mixture were properly applied. It has already been stated that it will require a minimum of 100 gallons of a 5-5-50 bordeaux mixture to protect adequately the foliage of an acre of potatoes when the vines cover the ground. Such a mixture contains 10 pounds of copper sulfate and, as the equivalent of metallic copper contained in copper sulfate crystals is approximately 25.5 per cent, 100 gallons of the mixture will contain an equivalent of 2.55 pounds of metallic copper. A monohydrated copper sulfate, such as used in copper-lime dust mixtures, contains approximately the equivalent of 35.2 per cent metallic copper. Manufacturers of copper dust mixtures indicate on the container the minimum percentage of copper present in the mixture. One readily can determine the correct amount of the various copper-lime dust mixtures to use on an acre by the use of the following proportion:

$$\text{percentage of copper in the dust} : 2.55 :: 100 : x$$

For the convenience of those using dusts the following table has been prepared, giving the amount of various copper-lime dusts having an equivalent of metallic copper equal to that in 100 gallons of a 5-5-50 bordeaux mixture when the copper sulfate used is in the form of a monohydrate.

TABLE 2. COMPARISON OF THE COPPER CONTENTS IN DUST AND LIQUID FUNGICIDES

| Percentage of copper | Proportion of monohydrate copper-sulfate and lime | Amount of dust needed to equal 100 gallons of a 5-5-50 bordeaux mixture (pounds) |
|----------------------|---------------------------------------------------|----------------------------------------------------------------------------------|
| 3.5.....             | 10-90                                             | 72.8                                                                             |
| 5.28.....            | 15-85                                             | 48.3                                                                             |
| 6.0.....             | 17-83                                             | 42.5                                                                             |
| 7.0.....             | 20-80                                             | 36.4                                                                             |
| 8.8.....             | 25-75                                             | 29.0                                                                             |

### Time and manner of application

The purpose of applying a dust to potato vines is identical to that of applying a spray, namely, to provide a uniform coating of a protective fungicide and insecticide to all susceptible parts. Generally speaking the same number of applications of dust as of spray will be needed during the season to give protection. The duster nozzles are adjusted to give a uniform distribution to all parts of the vine. When the copper-lime dust comes in contact with moisture on the leaf, the particles of copper sulfate and of lime go into solution and immediately combine to form a bordeaux mixture. If the dust is applied when there is no moisture on the leaf, some of it is likely to be blown off and there is also an undesirable air slaking of the lime upon continued exposure to the air before going into solution. For these reasons, applications are more effective when started at three or four o'clock in the morning and discontinued before the moisture has disappeared. The air at this time is usually quiet and favors uniform distribution. Machines may be equipped with a gasoline or acetylene lamp to provide illumination.

### Dusting machines

There are hand, traction, and power dusters. A good hand duster is practicable on small acreage and up to 5 or 10 acres. One grower considers them practicable on 20 acres, using several machines where the fields are on steep hillsides. The relative value of traction and power dusters has not been determined definitely. The power duster will give a stronger blast of air for blowing the dust onto the vines and will probably give a better distribution of the fungicide than will a traction duster.

### Injury

Some injury has been reported on potato foliage from the use of a 20-80 dust mixture when used immediately after the ingredients are mixed. The injury does not occur after the dust had been kept in tight containers for two weeks nor is there any appreciable injury with freshly mixed dust containing 15 per cent or less of the copper sulfate.

The operator of a hand duster may be severely injured if his clothing becomes wet from the moisture on the foliage. The dust making its way through the clothing causes the skin to blister and come off at places where the wet clothes rub against it. One man was disabled for a day or more and was lame for more than a week from such an injury. By wearing high-top boots, the trouble can largely be obviated.

### STORAGE

The purpose of storage is to keep the tubers from freezing or chilling and from overheating, to prevent and to retard the development of storage rot, and to retard excessive sprouting in the spring after the rest period is over. The extent to which these results are obtained indicates the degree of perfection of the storage house, so far as the keeping qualities of the tubers are concerned. Other factors, such as convenience and ease in filling the storage and removing stock from it, need not be considered here.

The rots that occur in storage in New York State are late-blight rot, *Fusarium* wound rot, *Fusarium*-wilt rot, black-leg rot, and black-heart

Infection of the tubers with late-blight rot takes place in the field from blighted vines. Only a relatively small amount of blight in late season, so little that it may not be noticeable, is sufficient to bring about a considerable amount of rot to the tubers if rainy weather prevails at that time. This rot can be prevented most easily by applications of a fungicide to the vines during the growing season. Should the vines be blighted, less infection of the tubers will take place if digging is delayed until all vines are dead. Delay in digging also permits many affected tubers to rot sufficiently to enable one to detect them when picking up potatoes and thus avoid placing them in storage. Tubers affected at harvest without showing evidence of it may develop rot later. Sorting the tubers a month after harvest will enable one to detect most of the affected potatoes. Keeping the temperature of the storage at 40° F. or below prevents development of the rot.

Most wound rots of the tuber are caused by a *Fusarium*, which is unable to penetrate the uninjured skin. To prevent this rot, it is important to handle the tubers with care while harvesting, grading, and otherwise working with them. Lowering the point of the digger so that considerable earth is moved and padding the kickers will aid in preventing injury. If tubers are picked in crates and if the crates are not over-filled and are used to carry the tubers on their way to the storage house, the possibility of bruising is eliminated. Much preventable bruising occurs from dumping the potatoes onto the cellar floor and from walking over them with heavy shoes. If a grower would realize that every bruise causes a blemish and that a dry rot develops in such bruises and spreads into the unbruised parts of the tuber, he would strive to avoid injury wherever possible. Good ventilation and low temperature in the storage house aid in preventing the development of this rot.

Before tubers are placed in the cellar or other storage house, it should be cleaned of refuse and dirt. If *Fusarium* storage rot has occurred

during the preceding storage period, it will be advisable, after cleaning, to disinfect the storage place with a 1-1000 corrosive-sublimate solution or with a copper-sulfate solution, applying these solutions with a broom to the floor, the walls, and the ceiling. Such an application will destroy the spores of the *Fusarium*, some of which otherwise might find a lodging place in a wound of the tuber. In sorting potatoes all rotted tubers should be removed from the vicinity of the storage place.

*Fusarium* wilt rot occurs from infections in the field. Control measures outlined on page 82 will help to keep this rot to a minimum. This is also the case with black-leg rot, for the control of which see page 90.

Black-heart is brought about by improper ventilation and high temperature. These conditions are likely to occur in the spring when the outside temperature rises and when the rest period of the tubers is over, as is indicated by the starting of the sprouts. Good ventilation may be obtained by providing air passages where more than 500 or 600 bushels are stored. False bottoms and sides made of boards or slats laid an inch apart will usually provide for a sufficient movement of air among the tubers. The escape of gases from the respiring tubers may be obtained through windows or better through ventilator shafts. There are various ways of regulating the temperature and provision for such regulation should be made in constructing the storage house. Where cellars are used for storage, the temperature can be kept down in the fall and for a considerable period in the spring by opening windows during the night and by keeping the warm air of the day from entering.

Although the potato tuber can withstand a temperature of a few degrees below freezing, it should not be permitted to fall below 32° F. for any length of time lest chilling results. A temperature of 40° F. is considered most satisfactory for the greater part of the storage period. Ideal conditions are those that will keep the tubers from sprouting until the time for their removal for planting or for market. As has already been pointed out, seed tubers should be removed from storage a few weeks in advance of planting in order to treat them and to permit the development of green sprouts.

### THE SEED PLOT

The purpose of the seed plot is to enable one to produce seed stock relatively free from degeneration diseases, as wilt, black leg, giant hills, weak hills, and varietal mixture. The seed plot may also be used for the selection of desirable types and of high-yielding strains. If one wishes to practice selection for these latter purposes, he should consult Cornell Extension Bulletin 125<sup>1</sup> in which the method is outlined.

<sup>1</sup> Hill-unit selection of potatoes, by J. R. Livermore.

Not all farmers are endowed by nature with the necessary patience and perseverance to do the work needed to make a seed plot successful, nor do all those possessing the necessary qualifications desire to engage in it. The relatively few who can and wish to do this will find the seed plot a means of improving stock and of maintaining the improvement year after year, if the region in which they are located is not favorable for the rapid spread of degeneration diseases. Stock thus improved and maintained should serve as foundation stock for other seed growers who do not wish to go to the trouble and the expense of maintaining a seed plot in this way but who are interested in propagating certified seed.

The seed used in the seed plot should be the best of the variety that can be obtained. It usually is better to go to considerable trouble to procure excellent stock to start with than to endeavor to improve stock that already contains a large percentage of disease. One may try two or three good strains during the first year or two, but, if this is done, more space will be required and more labor must be expended than if only one strain is grown. If one already has a strain that has given satisfaction in the past, it will probably be free enough from disease to be used for this purpose. If the selection is made from the bin, tubers of fairly uniform size and typical of the variety are chosen. The points set forth on page 4 should be given special consideration. The sprouting test is particularly important as it is helpful in eliminating diseased tubers at the start. Tuber indexing (page 36) is a more effective but, also, a more time-consuming method of doing this. Seed disinfection and subsequent handling is fully described on page 6 and this procedure should be followed carefully with tubers to be used in the seed plot.

The size of the seed plot will depend upon the number of bushels needed to plant the main field and the capacity of the soil to yield under average conditions. A seed plot ordinarily will not yield as high as will the main field because the hills are planted farther apart and there are sure to be some diseased hills to be removed. Ordinarily it may be calculated that an acre seed plot will yield tubers enough to plant ten acres.

The area selected for a seed plot should consist of potato soil in good tilth and sufficiently fertile to produce a good yield. Applications of manure and of commercial fertilizers are made as one would do for the main field, and good cultural conditions are provided throughout the season even if it is necessary to do hand work. It is essential that weeds be kept down so as not to interfere with the detection of diseased plants.

It is safer to select an area a hundred yards or more distant from the main field or from any other potatoes. If desired for the convenience of cultivation, it may adjoin some other cultivated crop as cabbage or corn. Some growers prefer to use one side of the main field of potatoes as a

seed plot and to rogue a sufficient number of adjoining rows in the main field to insure isolation from diseased plants. This may be done if the field already is low in disease content; even then the plot is not so safe from infection as when it is separated from other potatoes. If a location adjoining other potatoes should be selected, the side of the field from which the prevailing winds come is chosen as there is then less likelihood that aphids and other sucking insects will move from the main field to the seed plot. If one realized how important it is to protect the plot from virus-contaminated insects and that failure to do this would ruin the seed potatoes, he would decide upon the most suitable and practical location to eliminate these possibilities.

The seed plot may be planted at any time sufficiently early to enable the vines to produce a satisfactory crop. It has been observed, however, that, during some years at least, aphids and leaf hoppers are less troublesome in the latter part of the season. Should this observation prove to be a general rule, late-planted seed plots may be advisable to avoid infestations by these insects and the virus diseases carried by them. Immaturity of tubers, resulting from late planting, does not depreciate their value. The lateness at which such planting may be done in different parts of the State will depend upon the length of the growing season in each particular part.

It is advisable to plant the seed plot in tuber units, that is, all pieces of a tuber planted in adjoining hills. This requires that the planting shall be done by hand, but the extra labor involved will receive compensation by the greater certainty and ease with which undesirable plants can be detected. When this method is used, all plants coming from a single tuber will be in adjoining hills. When a number of such plants are together, even slight symptoms of disease, such as may be exhibited by plants of some varieties when affected with spindle-tuber or when mosaic mottling is masked, will exhibit a sufficient contrast to enable one to detect them, whereas, when not planted in tuber-units, some undesirable plants are very likely to be overlooked or the diagnosis be less certain. This method may be followed to advantage even when the hill-unit method of selection is being practiced. Planting in check rows is not necessary, yet is advisable because it permits the separation of diseased and healthy plants when the vines are small and before the diseased ones are removed.

After the plants are large enough to exhibit symptoms of degeneration diseases, the seed plot is rogued. The plants to be rogued and the method of roguing have been described fully on pages 17 to 19. The seed plot should be rogued several times during the season in order to insure the prompt removal of diseased plants and thus prevent the spread of the virus to adjoining plants. Care taken in this work will be repaid by the

smaller percentage of diseased plants that will appear in the main field and, therefore, by the reduction of labor in roguing the field. Although the remainder are apparently healthy, the presence of a degeneration disease in one or more hills of a tuber unit is sufficient reason for the removal of all hills of that unit. The apparently healthy hills may actually be healthy but there is a probability that they are diseased and have the symptoms masked. A diseased hill that apparently is healthy is as much a source of inoculum to adjoining healthy plants as one plainly affected.

It is especially important that applications of a spray or dust be made regularly and thoroughly to the seed plot to prevent blight, hopper burn, and potato-beetle injury. Bordeaux mixture applied as a spray is more effective than is dust in repelling leaf hoppers and aphids, but is usually more inconvenient to apply to the small area occupied by a seed plot, especially when isolated from the main field. This must not, however, be an excuse for neglecting the seed plot, for the value of the crop is out of all proportion to the cost of making all needed applications to give adequate protection. The use of a free-nicotine dust may well be used to keep the population of sucking insects to a minimum. The directions for the preparation of bordeaux mixture and dust mixtures and their application are given on pages 19 to 31.

During the season and at harvest it is possible to select hills for vigor, uniformity in tuber size and shape, conformity to type, and yield. Directions for making such a selection are give in Cornell Extension Bulletin 125.

The tubers harvested from the healthy plants left in the seed plot are stored in a bin separate from other potatoes or in crates, barrels, or bags, plainly marked and kept separate from others so that they may be identified readily. The conditions necessary for proper storage of seed tubers are similar to those for table stock and have been described on page 32.

### INDEXING TUBERS

Ordinarily, when one starts with reasonably healthy stock, it is possible to maintain it in a healthy condition and even eliminate degeneration diseases entirely by means of the seed plot. There is an advantage, however, in starting the seed plot with stock that is free from such diseases. Then, too, an occasional grower may have stock which he wishes to propagate because of its quality or yielding capacity or for some other reason, although it contains a considerable percentage of disease. A method by which the diseased tubers can be eliminated before planting would greatly simplify the work of maintaining the stock in a healthy condition from year to year. This can be done with more or less certainty by indexing the tubers.

A tuber is indexed by growing a sprout from one eye cut from the tuber. When this sprout has developed into a vine from 8 to 12 inches high, it usually will show symptoms of mosaic, leaf roll, or yellow dwarf if the tuber is affected with one or the other of these diseases. Should it show such symptoms, the tuber is discarded for seed purposes. On the other hand, should the vine appear to be healthy, the remainder of the tuber is used for planting. Rarely a vine will appear healthy when other pieces from the same tuber will produce affected plants. Ordinarily the results obtained from the vine grown from one eye, holds true for the other eyes of the same tuber.

The tubers coming from one hill may be indexed by planting a single tuber or a part of a tuber from that hill and observing the vine characters that develop. Hill indexing, however, has proved to be less reliable than tuber indexing, since one or more tubers of a hill may produce healthy vines while the other tubers will produce diseased vines.

A method of tuber indexing that has proved satisfactory is as follows: A number of rather large uniform tubers of typical shape for the variety are selected. Large tubers provide a larger piece about each eye than do smaller ones. As many tubers may be selected as time and space for growing will permit. Each tuber is numbered consecutively, the number being written on the skin with a soft lead pencil or India ink. A piece containing one eye is then removed from each tuber and planted in a 3-inch pot or in a greenhouse bench. The remainder of the cut tubers are placed in a cold dry storage until the vines from the planted piece have developed sufficiently to permit a determination of the diseases present. As each piece is cut and planted, the pot or space in the bench is given the number corresponding to the one on the tuber from which it is taken. It is very essential that no mistake be made in this numbering. The planted pieces are given sufficient moisture and temperature for rapid growth. Bottom heat usually will force a rapid growth. After the shoots are from 4 to 6 inches high, the plants are placed in a cool house where mosaic symptoms will develop if the disease is present. The plants from each piece are then examined carefully and the number assigned to each one showing undesirable character is recorded. When the reading is completed, the tubers are checked and those having a number corresponding to that on an undesirable plant are discarded. Each of the remaining tubers are cut into as many pieces as will produce plants and planted out-of-doors in tuber units. The place selected for planting must be isolated from other plantings of potatoes and the soil and cultural conditions must be suitable for the best development of the plants. This plot is inspected frequently after the plants are large enough to show symptoms of disease. Any plant showing the presence of a degeneration disease is reason enough for roguing out all the plants in the same unit. The crop from the remaining

plants is harvested and stored separate from other stocks and is used the following year for the seed plot.

As soon as the rest period is over, tubers may be indexed by planting the indexing piece in a greenhouse. A reading can be made in time to plant the remainder of the tubers out-of-doors in the spring. Most potato growers do not have greenhouse space available for such a test. Experiments, however, have indicated that it may be possible to plant the indexing pieces out-of-doors in May and get readings from the resulting vines in time to make a late planting of the remainder of the tubers. The soil selected for planting the indexing pieces must be fairly warm and well drained. Not as good results will always be obtained by such out-of-door indexing since the temperature conditions are not controlled. Some years they will be so high at times as to mask mosaic symptoms and to confuse one in respect to leaf-roll symptoms. Dusting the cut surfaces with sulfur will aid in preventing decay as will also a treatment with corrosive sublimate before the piece is removed. Although no data are available, it has been suggested that a hotbed or even a cold frame would prove more desirable for growing the indexing pieces than would a place directly out-of-doors.

### DEGENERATION DISEASES

Degeneration diseases include those infectious diseases, the cause of which is unknown, that can be transmitted by means of the sap from a diseased to a healthy plant either through a mutilated surface by injection, or by other means. Transmission from season to season occurs through the use of tubers from affected plants. In general, but not always, degeneration diseases are characterized by a dwarfing of some parts of the affected plant; by a chlorosis, or yellowing, which is diffuse in some diseases and restricted to scattered areas of the foliage in others; by an abnormal shape of the leaf, stem, or tuber; and by a diminished yield of marketable tubers due to a reduction in their size or number, to abnormality in their shape, to cracking, or to the presence of discolored areas in the flesh.

In this group are included mosaic and its various types consisting of symptom complexes to which the terms *mild mosaic*, *leaf-rolling mosaic*, *rugose mosaic*, or *crinkle*, and *curly dwarf* have been applied. Streak, leaf roll, spindle tuber, and probably yellow dwarf and giant hills may also be added. A plant may become affected with only one of these diseases or it may have two or more at the same time, in which case the symptom complex of the combination may be considerably different from that of any one of them, making recognition of them difficult. Then, too, the symptoms of a disease on one variety may differ somewhat from those

of the same disease on another variety. The symptoms of a disease may vary with the age of the plant, with the time that has elapsed since infection took place, and with soil and climatic conditions. For these reasons it is not always easy, even for an experienced observer, to determine with certainty which degeneration disease, if any, is affecting a plant. It is impossible to describe each of these diseases in such a way that the reader, depending alone on the description, may invariably diagnose correctly plants affected with them. But, typical cases of individual diseases do not present so much difficulty, for they exhibit symptoms characteristic of the disease with which the plant is affected.

Control measures as already discussed consist mainly in the use of seed tubers from fields free, or comparatively so, from these diseases, and in maintaining such comparative freedom by the use of an isolated tuber-unit seed plot from which all affected plants are removed as soon as they can be detected.

### MOSAIC

Recent investigations indicate that there are many kinds of mosaic each of which is more or less restricted as to the species of plants it is able to attack. At least three mosaic diseases occur on potatoes and one of these has been transmitted to tomato, tobacco, and possibly other plants. The ordinary mosaic of tobacco and tomato can also be transmitted to potatoes but is a different disease from any of the mosaic diseases naturally occurring on the latter host. The name "mild mosaic" has been applied to the type most commonly found on potatoes. The other types are named "leaf-rolling mosaic" and "rugose mosaic."

Judging from field observations, there is considerable variation in the susceptibility of different varieties of potatoes to mosaic. Bliss Triumph is very susceptible and the Green Mountain type scarcely less so. On the other hand, Irish Cobbler, Early Ohio, and the Rural type are more generally resistant, although at times they show a considerable percentage of diseased plants. The extent of the injury in these varieties is apparently not so great as in the case of those mentioned as most susceptible.

Not many years ago the disease now known as mosaic was included with leaf roll and curly dwarf under the term "curl." In Germany the name "Krauselkrankheit" possibly was applied to all three and also included the bacterial ring disease. The term "curly dwarf" is now thought by some to have included at least two distinct diseases,—"unmottled curly dwarf" and "rugose mosaic."

Mosaic probably has existed for many years. A disease that compares in many ways with it was described in the *Gardner's Chronicle* as early as 1847 and it is reported that certain Scottish farmers can remember having observed the characters of the disease for forty years. It now occurs in

all parts of the British Isles. Orton observed mosaic in Germany in 1911 where it was not uncommon on some varieties. It was first reported in this country in Maine in 1912 but probably was present much earlier. It is now recognized throughout this country and Canada. Apparently it is



FIGURE 7. MOTTLED APPEARANCE OF A MOSAIC LEAF

less prevalent in some sections than in others; for example, in northern Ontario it is said to be of little importance even on the Green Mountain variety.

Plants affected with mosaic yield about two-thirds as much as do healthy plants, the variation in yield depending upon the severity of infection.

### Symptoms

Affected plants can usually be recognized by the mottled appearance of the foliage (figure 7). The name *mosaic* was first given to this disease on tobacco because of this character. The mottled appearance is due to the contrast between the small light green areas which are scattered over the leaves and the dark green of the healthy parts. These areas may be numerous or there may be but a few. Sometimes they are only faintly discernible and can be seen only by shading the plant, while in other cases they are so sharply defined that they can be detected readily in direct sunlight. Although under cool conditions this mottling is a rather constant character of mosaic, in continued hot weather it does not develop and is said to be masked. Experiments have shown that complete masking will occur after seven days at a temperature of about 78° F. Not only do the new leaves show no mottling but the older affected leaves gradually lose their symptoms. Even at 68° F., the symptoms eventually disappear. In hot seasons, as in 1921, it may be impossible to detect mosaic.

When plants are but slightly affected, the foliage, except for the mottling, has nearly the same appearance as has that of healthy plants and the vines may be as large and as vigorous; but, when more severely affected, the leaflets become more or less wrinkled and ruffled, and the edges often curl downward. This condition has been compared to that occurring naturally on leaves of kale and savoy cabbage. There is a tendency for the stalks to recline on the ground earlier than is normal for healthy plants. Badly affected plants are more susceptible to tipburn than are healthy ones, and usually die earlier than normal. Tubers from affected plants show no visible symptoms, so that there is no way now known of detecting them.

Leaf-rolling mosaic is the name that has been given by some investigators to a mosaic type in which the mottling is more diffuse than in mild mosaic and there is a wrinkling, a slight ruffling, and a rolling of the upper leaves. This disease is transmitted by inoculation and is carried by the tubers.

Rugose mosaic is another mosaic that corresponds somewhat in symptoms to a disease that has been named "crinkle" and also to the disease that was formerly known as "curly dwarf" and as "mosaic dwarf." It is differentiated from other types of mosaic by a less distinct and more diffuse mottling; by a more rugose type of wrinkling; a tendency of the stems and petioles to be brittle and of the leaves and stems to become spotted or streaked with brown or black necrotic areas; and for the leaves to drop off, beginning with those at the base and followed progressively with those above. These characters—brittle stems and petioles and streaked or spotted leaves—are also symptoms of streak. The tubers become markedly reduced in size.

Curly dwarf is a term that has been used to designate a condition in which the plant becomes markedly dwarfed; the foliage curled and wrinkled; and the stems, branches, petioles, and even midribs and veins fail to develop to normal length so that the foliage is clustered about the stems, particularly in the upper parts. The puckered and wrinkled condition of the foliage has some resemblance to the leaves of kale or savoy cabbage. The color of the leaf remains a normal green or may be even a darker color. This seems to differentiate it from any mosaic type. However, plants otherwise similar to curly dwarf, but with mottling, have been observed and have been ascribed to a severe mosaic or to a condition known as "mosaic dwarf." A condition very similar, if not identical to curly dwarf has been designated "unmottled curly dwarf." When this disease is present, the stems and petioles are very brittle and sometimes the under side of the veins and the vascular tissue within the petiole and stems turn brown. The tubers in all the cases of dwarfing are very much reduced in size. It has not been clearly shown whether the various dwarfed conditions are due to one disease or whether they are expressions of several diseases.

### Cause

Mosaic has been ascribed to various causes but in no case has it ever been proved that any one was responsible; all but three theories have been almost certainly disproved. The oldest one of these involves the production of disturbing substances by the cells of the affected plants themselves. This theory is not generally accepted by pathologists. The second theory, and the one having the largest number of adherents, is that the disease is caused by microorganisms too small to be seen even with the high power of the microscope. Until very recently all attempts to cultivate these organisms resulted in failure. In a recent report it is claimed that there was an increase in the infective particles of tobacco mosaic in filtered juice of tomato plants. It is true that peculiar bodies have been found within the cells of diseased plants, but it is not known whether they have any connection with the causal organism. The most recent hypothesis is that the disease may be due to the presence in the cells of one plant of particles of protoplasm from another species. This theory is supported by the fact that mosaic symptoms can be produced in healthy plants of tobacco and related species by introducing into them the juice from supposedly healthy potato plants.

Mosaic can be transmitted to healthy potato plants by introducing juice from a mosaic potato plant. Inoculation takes place under ordinary field conditions by means of aphids feeding upon healthy plants after having visited mosaic plants. In Maine, the green and rosy aphid, which passes the winter in the egg stage upon rose bushes, is the principal offender. There is some evidence that the leaf hopper and the tarnished plant bug

may also transmit mosaic. All three are sucking insects. There is good evidence that the flea beetle and the Colorado potato beetle cannot carry mosaic.

When fields are located within 300 yards of each other, mosaic may be transmitted from one to the other; but ordinarily an intervening distance of 50 yards will protect a field from appreciable infection.

Plants may show evidence of the disease in the year they are inoculated, although usually no visible symptoms develop the same season. Tubers of such plants will produce diseased plants. Mosaic does not spread from one tuber to another in the bin. The soil is not a source of inoculum, so that there will be no increase in the disease from planting tubers in soil which had previously produced affected plants.

### Control

It must be evident from the statements made that control consists in the use of seed tubers free or comparatively so from this disease, in preventing infection by locating the field at a distance from affected ones, and by the removal of affected individuals as soon as it is possible to detect them. Furthermore, control consists in reducing the number of insects capable of transmitting the disease. Ordinarily these measures are not practicable when applied to the main fields but it usually is practicable to apply them to a seed plot in which is grown the seed for the main fields. Refer to the control measures discussed on pages 16 and 33.

### LEAF ROLL

Leaf roll as known at the present time is a nonparasitic disease of the potato and does not occur on other plants. It does not affect all varieties in the same degree, and different varieties vary markedly in the percentage of affected plants that may be found in a field. No one has determined by artificial inoculations the susceptibility of varieties, but, from observations made, the indications are that Early Rose, Early Ohio, Burpee's Extra Early, White Elephant, American Wonder, Beauty of Hebron, Rural New Yorker No. 2, Sir Walter Raleigh, Empire State, and some other less-known varieties are very susceptible. Irish Cobbler, Bliss Triumph, Garnet Chili, and Carmen No. 1, are also reported as being rather susceptible. The Green Mountain type usually shows fewer affected plants than the other varieties named, but those that are affected often become much dwarfed and yield poorly. Gold Nugget is said to be very resistant.

Some scientists named the disease phloem-necrosis or lepto-necrosis. Growers have designated it as curly leaf and leaf curl,—names that have also been applied to mosaic. Notwithstanding the fact that the rolling of leaves is associated with other diseases of the potato and that potatoes may be affected with leaf roll without showing this characteristic symptom,

it still is preferable to apply the name leaf roll only to this particular disease since it has borne the name so long.

From early descriptions it appears probable that leaf roll has been present in Germany for more than sixty years. It was not until 1905\* that the disease attracted general attention, but since 1907 it has been known to be responsible for heavy losses in Europe. It was observed first in this country in 1911 when a big reduction in yield in Colorado fields was attributed to leaf roll. It now occurs generally throughout most sections of the country, and, judging from the literature, throughout the world wherever potatoes are grown.

Leaf roll is of considerable economic importance, affecting as it does so many commercial varieties and so markedly reducing the yield of affected plants. Leaf roll and mosaic have been held to be largely responsible for potatoes "running-out." Determinations made from many New York State fields indicate a loss of more than 60 per cent from the disease. It is evident to anyone examining affected plants that the reduction in yield



FIGURE 8. A DWARFED LEAF-ROLL PLANT COMPARED WITH A HEALTHY ONE

is very great, and, since it occurs so generally year after year, leaf roll must be considered as one of the most important diseases of potatoes.

### Symptoms

Inasmuch as rolling of the leaflets, one of the symptoms of leaf roll, also occurs when plants are affected with wilt, Rhizoctoniose, black leg, and sometimes when the plants suffer from drought or from too wet soil, it is necessary that all the symptoms of this disease be considered when identifying it. It should be remembered, too, that often not all the symptoms of leaf roll will be evident at any one time and that, during the early stages of the disease, scarcely any of these symptoms will be manifested.

Affected plants usually are dwarfed. In badly affected plants this is very pronounced. Not only are the stalks shorter but they are slenderer and the leaf area is much reduced (figure 8).

The stalks have a tendency to remain upright throughout the life of the plant. The leafstalks have a more upright growth than do those of healthy plants, producing an appearance of starkness. During the early stages of infection this is not noticed.

The leaves have a tendency to roll upward. This may often be observed in the lower leaves, the leaflets of which, especially the terminal ones, have a spoon-shaped appearance. Sometimes only the lower leaves show this symptom; other affected plants may show a rolling of the upper leaves as well. The leaflets in such cases roll upward parallel with the midrib, giving the leaflet a funnel-shaped appearance. These rolled leaflets, especially on the lower leaves, are thicker than normal, have a leathery texture, and rattle when shaken. This rolled and thickened condition of the leaves is due to the accumulation of starch in the cells which is not removed as produced, as is done in healthy plants.

Affected plants are usually off-color; that is, they are lighter green than normal, the yellow being more pronounced in some plants than in others. With some varieties the margins and the tips of the leaflet, especially those of the upper leaves, have a purplish, violet, or even a red tint.

The seed piece of affected plants may usually be found intact. This may be true also of plants affected with other diseases. Ordinarily, the tubers formed are smaller and fewer than those produced on healthy plants and it often happens that they are formed on short stolons or are sessile. This has also been found to be true of plants affected with yellow dwarf. The affected tubers usually show no external or internal lesions or discoloration, so that they cannot be picked out from healthy ones. There have been reports that affected tubers are harder than healthy ones and that they sometimes show a net necrosis, but these symptoms cannot be depended upon. Tubers from leaf-roll plants may produce spindling sprouts. In such cases affected tubers do not become so shrunk or so withered in the spring as do healthy tubers that have sprouted excessively. Not all

leaf-roll tubers produce spindling sprouts and not all tubers producing spindling sprouts are effected with leaf roll. The vines die earlier than do



FIGURE 9. LEAF ROLL SHOWING STARTING EFFECT OF PLANT

healthy ones. In general, we may say that leaf roll tends to check the growth of all parts of the plants, to cause leaf rolling and yellowing, and to reduce the yield very materially.

Dutch writers have distinguished between an early stage called *primary* and a later, *secondary*, stage of the disease. The symptoms already given are those of the secondary stage. The primary stage may be observed in July and later on plants infected during the current year. This begins with

a rolling and discoloration of the leaves at the top of the plant. These symptoms are more easily confused with those of other diseases than are the secondary symptoms.

One symptom that commonly is present but seen only by a microscopic examination of sections of the stem, is a necrosis, or death, of parts of the phloem tissue. The name "phloem-necrosis" has, therefore, been given the disease. This condition of the phloem is said by some to prevent the normal movement of the starch from the leaves so that it accumulates in the leaves and causes rolling and stiffness of these parts. Other writers claim that the accumulation of starch in the leaves of affected plants is due to inactivity of the starch enzyme, diastase.

### Cause

It is not yet known what causes leaf roll. Many agencies have been suggested, as physiological disturbances, enzymes, unbalanced fertilizer, the absorption of too much of one salt, lack of minerals or an oversupply of them, long continued cold and dampness, use of unripe seed or use of mature seed, poor culture, lack of seed selection, varietal degeneration, fungi, bacteria, and ultramicroscopic organisms. The fact that so many causes are assigned to the disease indicates a lack of knowledge concerning it.

Progress, however, has been made in discovering the means by which the disease may be transmitted. It now is definitely known that tubers from affected plants will almost always produce leaf-roll plants, but that the disease is not transmitted to the true seed formed in potato balls. The disease has been transmitted artificially by tuber grafts, vine grafts, and the use of two species of potato aphids. So far it has been found impossible to transmit leaf roll by the injection of juice from diseased plants, by the rubbing of healthy leaves with leaves from diseased plants, by the use of the same cutting knife for healthy tubers as for diseased tubers, by the flea beetle, or by the Colorado potato beetle. The disease is not transmitted by means of the soil nor by drainage water, but affected tubers left in the soil over winter, on sprouting, will serve as sources of inoculum. The primary stages of the disease appear in from twenty-four to twenty-nine days after contaminated aphids are removed from affected to healthy plants. It has been shown in England that the disease may be transmitted by aphids while the tubers are sprouting before being planted and that sprouts thus infected will give rise to the secondary, or more advanced, type of the disease.

Experiments have been conducted in Holland, in Canada, and in Bermuda to determine the distance the disease may be transmitted from an

affected to a healthy plant. The greatest percentage of infection is found on healthy plants growing between rows of affected plants or in adjoining rows; this percentage decreases rapidly as the distance from the affected rows increases, so that there are but few plants affected in the fifth row away. Even at a distance of 8 feet the amount of infection is slight. It is uncertain at what distance the plants would remain entirely free from infection, this depending upon the distance traveled by contaminated aphids from an affected plant. It has been observed that the disease spreads much farther among plants in the shade of trees than among those in direct sunlight, for shaded plants are visited more frequently by insects.

Just what effect the weather has on the appearance of leaf roll is not known. Some observers declare that the disease appears to be more prevalent the year following a hot season than the year following a cool season. It is claimed that the disease is more prevalent on Bliss Triumph in Bermuda and on Long Island than it is in northern Maine. It is also reported to be much more severe in southern Ontario than it is in northern Ontario or in Quebec. Since it is now known that aphids can transmit the disease, it seems that weather conditions favorable for the development and dissemination of these insects would favor its spread. More extensive observations of weather conditions in the light of this new knowledge is necessary before general conclusions can be reached.

### Control

In order to grow potatoes so that there will be little or no loss from leaf roll, it is necessary to use seed tubers from leaf-roll-free plants. For the potato grower who buys his seed year after year this means that either he must visit the localities where such seed is being grown or buy seed that has been recommended by others as disease free. Certified seed should be comparatively free from leaf roll. For the persons who grow seed potatoes for sale or for their own use the problem is more complex, for they not only must use healthy tubers for planting but must prevent new infections during the growing season. In regions where aphids are scarce there will be little danger of infection. By maintaining a seed plot as directed on page 33 it will be possible to keep the disease at a minimum by the early roguing of affected plants. In sections where aphids are abundant it will be necessary to use the greatest precaution in keeping affected plants rogued out and in taking measures to keep the aphids under control. If leaf roll should appear to the extent of 5 per cent in a field, it is very likely that such stock will be unsatisfactory for seed purposes. The grower should obtain new stock from an unaffected source and plant it in an isolated field if he wishes to grow healthy potatoes.

### SPINDLE TUBER

Spindle tuber, so far as known, is a disease confined to the potato. All varieties used in experiments with the disease are susceptible; the symptoms, however, are more pronounced on some varieties than on others.

The name "spindle tuber" is now generally used although the term "spindling tuber" has been applied to this disease. The name "marginal leaf roll" was given by a Dutch pathologist to a disease having similar leaf characters and has been applied to spindle tuber in this country.

The elongated condition of affected tubers has long been observed but was thought to be due to environmental conditions or to a natural variation. Workers in this country definitely showed in 1922 that elongated and spindle-shaped tubers associated with certain other tuber and vine characters are the symptoms of a transmissible disease. This disease while apparently more prevalent in some sections has been observed throughout the United States. It occurs in all sections of New York but has never appeared to be very prevalent except on certain stocks.

The loss from this disease is of a two-fold character—it reduces the yield and injures the market quality of the stock. Records indicate that the spindle-tuber disease may reduce the yield one-half or more. The reduction depends on the percentage of affected plants present and the severity of the disease upon the plant. If more than 5 per cent are present, the market price may be lowered. There is also a potential loss, not fully realized by all potato growers, due to the danger of healthy plants becoming infected from the diseased plants in the field. Once the disease is present in stock it will continue to increase from year to year until the stock is worthless for seed.

### Symptoms

Spindle tuber affects not only the tubers but the vines and leaves as well. If the disease is contracted during a previous year, both vines and tubers will show the symptoms, but, if infection occurs early in the season, the upper part of the vines and some of the tubers may show symptoms of the disease the same year. If the infection occurs late in the season, neither vines nor tubers are likely to show any symptoms that year, but, when tubers of such plants are used for seed, the resulting vines and tubers usually show the disease. The symptoms are not readily distinguished except in the advanced stages and are more marked on some varieties than on others.

Tubers from affected plants are elongated and cylindrical in shape and may be irregular with tapering ends. The eyes are shallower and more numerous than normal, but prominent "eyebrows" make them more conspicuous; the eyes may even bulge in severe cases. Affected tubers are said

to be more subject to growth cracks. The skin may be smoother. On red potatoes, like Bliss Triumph and Spaulding Rose 4, the color becomes lighter red or pink or these colors may disappear or appear in blotches. Cream-colored varieties may take on a yellowish appearance.

Affected tubers sprout more slowly than do healthy ones or not at all. The sprouts are sometimes spindling, and vines from affected tubers are inclined to be smaller throughout the season. The vines are upright and stiff and the leaves are produced at a sharp angle to the stem as is done when plants are affected with leaf roll. There is an inclination for the leaflets to roll upward along the midrib and for the margins to be wavy, but those of the lower leaves do not have the spoon-shaped appearance, the thickness, nor the brittle texture of leaf-roll-affected plants. The leaflets are smaller and narrower than healthy ones and have a tendency to grow lop-sided because the midvein curves sideways. The leaflets, particularly the terminal ones, are sometimes twisted so that part of the blade assumes a vertical position. The color is a darker green than normal, especially when the plants are young. It is difficult to detect affected plants of some varieties from the above-ground symptoms and it is then necessary to examine the tubers to make sure of one's diagnosis.

### Cause

The cause of spindle tuber is not known but is believed to be similar in nature to the agency causing leaf roll, mosaic, and other degeneration disease. It is known that the disease can be transmitted from year to year by means of the tubers and that the severity of the disease increases with continued planting. It has been transmitted from affected to healthy plants by means of aphids, leaf mutilations, tuber grafts, and stem grafts. Under field conditions the disease is transmitted from plant to plant by aphids and possibly other sucking insects infesting the potato. It is probable that it is transmitted also by means of the cutting knife. The soil does not become infested and, therefore, is not a source of danger.

Just how far the disease may spread is not known but the probability of healthy plants becoming infected depends upon their nearness to diseased plants. The additional factors that determine the extent of the spread of the disease are the climatic conditions which determine the number, distribution, and dispersal of insect carriers and which influence the length of the growing season.

### Control

Control of spindle tuber is based on the same procedure as outlined for other degeneration diseases (page 17). It is possible to reduce the number of affected plants at the start by eliminating all the ill-shaped tubers, but this should be attempted only when the percentage of diseased

individuals is small. It is not possible to eliminate all of the affected tubers, for not all will show evidence of the disease.

### YELLOW DWARF

Yellow dwarf, a disease confined, so far as known, to potatoes, affects many varieties grown in this State. No variety is known to be resistant. Rural varieties appear to be less often affected than do Green Mountain types.

The disease was first reported during 1917 in Clinton County, New York, but soon after was found in nineteen additional counties. According to the testimony of growers, it was present at least ten years previous to 1917. It has now been observed in nearly every county in the State but appears to be more prevalent in the northeastern section. It has been reported in southern Vermont and has appeared in New Jersey and Florida in fields planted with New York seed.

Affected plants produce almost no marketable tubers. Except for black wart, there is, perhaps, no other disease of the potato that so completely renders it worthless. Fortunately, the disease does not often affect a large percentage of plants. In the fields of New York State in which it has been observed during the past eight years, only a few have shown more than 2 or 3 per cent and many less than 1 per cent. On the other hand, as high as 30 per cent of affected plants have been found in a field, and this shows the extent to which it may develop under favorable conditions. It is not, however, a disease that need cause any alarm. Seed growers, in whose fields it has occurred, have been able to keep it down easily to within the 1 per cent required for certification.

### Symptoms

The pronounced symptoms of the disease are indicated in the name "yellow dwarf." In severe cases the plant may not attain a height of more than 2 or 3 inches although the one or two stalks that do appear are mostly stocky. The foliage soon changes to a yellowish green color and the shoot dies from the tip downward. In less severe cases the plant may grow to a greater height, and the tips may have a rosetted appearance. The characteristic dying from the top downward almost always takes place. The axillary buds and shoots of the upper part of the vine also soon die. Affected plants die down entirely much earlier than is normal for the variety.

The leaflets of affected plants, especially those toward the top, have a tendency to fold or roll lengthwise resembling in some respects leaf roll. This is not, however, a constant character. The rolled leaflets of blue-sprout varieties take on a purplish color where exposed to direct sunlight.

The yellow color first appears in the base of the lower top leaflets and becomes predominate there as the disease progresses. On some leaves

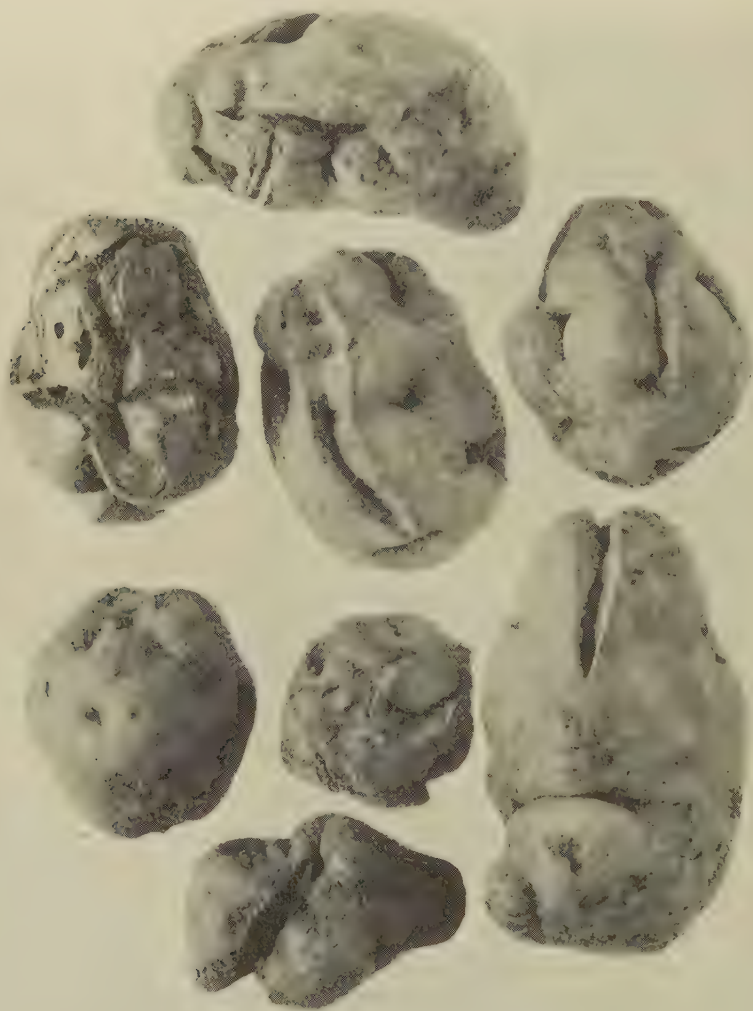


FIGURE 10. YELLOW DWARF CAUSES CRACKING OF TUBERS

the lower leaflets lose all green color and the yellow takes on a lighter tint becoming almost white. Affected plants seem to show a greater susceptibility to tip and marginal leaf burn than do healthy ones.

On full-grown plants the apex of a single stalk may show the yellowing

and rosetting characteristic of the disease. This seems to indicate that infection has taken place at some time during the growing season.

A longitudinal section of the entire length of an affected stalk reveals the presence of rusty-colored specks in the pith and the cortex of the upper part and sometimes in the lower part of the stalk. These specks are most abundant in the nodes but may occur also in the internodes. They are so numerous in the tissues of axillary and terminal shoots as to give a rusty-brown color to the whole shoot. When they are abundant or are located near the surface, the discoloration can easily be observed through the epidermis.

Tubers from badly affected plants are mostly very small, are irregular in shape, and sometime cracked. Generally the tubers of such plants are sessile or are attached to short stolons as is true also in leaf-roll-affected tubers. Sometimes the tubers are irregular in outline or are very knobby, although smooth normal-shaped ones are produced. The cracked condition is characteristic of the disease. These cracks first appear in the sides of the tuber and may later extend from one end to the other (figure 10). Occasionally there are several cracks radiating from the bud end. They have the appearance of growth cracks due to stress within the tuber. That a stress actually exists before the cracks appear is shown by the readiness with which such tubers split open when a knife is inserted. The depth of the cracks vary, but commonly they extend inward a quarter of an inch or more. The exposed flesh in the crack may become covered with a corky



FIGURE 11. YELLOW DWARF CAUSES INTERNAL BROWN SPOTS OF TUBERS

layer before harvest so that loss of moisture through these wounds, as well as an infection from rot-producing organisms, is prevented.

Discoloration of the flesh of affected tubers almost always takes place. This discoloration consists of small rusty-brown specks or areas in the cortex and the outer and inner medullary tissue (figure 11). These specks may be few and scattered or may be so numerous as to appear massed. The discoloration does not appear in streaks as is usual with wilt diseases and frost necrosis. Longitudinal sections show it to be most pronounced at the middle of the tuber but it commonly occurs in the bud end and sometimes at the stem end. It is rather evident that this discoloration does not necessarily occur first at the stem end as is true for tubers affected with wilt.

Occasionally, tubers from affected plants are found that show no indication of disease either externally or internally. Healthy-appearing tubers from affected plants show more prominent lenticels than do actually healthy tubers. Sometimes the only evidence of disease is one or a few small gray or grayish brown spots in the cortex. A large percentage of the tubers from affected plants are worthless for table stock or for seed. Plants affected late in the season may produce some marketable tubers, but these may be affected internally and consequently be of no value.

When one or more shoots of a hill appear healthy and the others are affected, the tubers from the apparently healthy vines sometimes appear normal while those attached to the affected vines show the characteristic symptoms of the disease. It has not yet been shown whether such apparently healthy tubers will produce vines free from the diseases.

The seed piece is commonly intact in the yellow-dwarf plants that have been observed in the field. This condition has also been reported to be of common occurrence in the plants that have leaf roll.

### Cause

The cause of yellow dwarf is not known. In some respects it resembles other degeneration diseases and for that reason has here been classed with them. The disease apparently is transmitted from plant to plant in the field but conclusive proof of this has not been obtained. Observations indicate that the causal factor may live from year to year in the soil, and in this respect it seems to differ from other degeneration diseases. When visibly affected tubers are planted, a spindling dwarfed vine commonly is produced which does not resemble yellow dwarf. More recent experiments in controlled temperature chambers have indicated that temperature is a factor in producing typical symptoms. Tubers produced on recently infected plants showing no visible symptoms are probably responsible for the appearance of most of the disease found in fields, as visibly affected tubers almost invariably are discarded. Since affected plants largely

produce either only very small tubers or larger tubers visibly affected, the chances of the disease increasing by means of infected seed are not great. In most cases infection from the soil or insect transmission probably accounts for the perpetuation of the disease.

### Control

Measures for the control of yellow dwarf are similar to those required for the control of other degeneration diseases. In view of the possibility of soil infection, one should also give consideration to crop rotation. For more detailed control measures refer to pages 17 and 33.

### STREAK

Streak, a disease of potatoes, is found only occasionally and then rarely more than one or two plants can be located. In this country it has been observed on Green Mountain, Evergreen, Early Ohio, Factor, and on a number of seedlings, and is known to occur on several European varieties.

The disease, although very destructive to the plant attacked, does not cause any appreciable loss because it appears so rarely. In one or two instances it has been reported to have spread through a field.

Streak is said to occur more commonly in Europe than in this country. It has been observed in Maine, New York, Wisconsin, Idaho, Washington, and eastern Canada, and it probably occurs sparingly in other potato regions. It is called "stipple-streak" in Holland, and is regarded by some to be identical with a condition known as leaf-drop described as a separate disease by other investigators.

### Symptoms

When the disease first appears on the plant, it exhibits elongated or angular, dark-brown or black, spots on the upper surface of full-grown leaves. These spots resemble in some ways those of early-blight although the streak spots, instead of being bordered by veins, may extend for some distance along them. A close examination of the plant will usually reveal dark longitudinal streaks along the veins, petioles, and stem, hence the name "streak." The main stem and the petioles of affected leaves are extremely brittle, snapping off sharply when handled.

The progress of the disease is rapid and destructive. Within a few days of its first appearance the petiole collapses and the leaf falls over and dries up, or the petiole breaks at its attachment to the stem and hangs by a thread. The first leaves to show the symptoms are those part way down the stem. Other leaves above and below soon show similar symptoms until after a time there are but a few, small, green leaves at the top. The

entire plant dies much earlier than does a healthy plant. The disease appears in late July or more commonly in August after the plant has made considerable growth.

The tubers from diseased plants do not appear to be affected and the only apparent injury is a reduction in size and consequently in yield due to the earlier death of the plant. However, if such tubers are planted the following year, the vines produced by them will be dwarfed exceedingly, often attaining a height of only a few inches and at most not much more than 12 or 15 inches. The stem as well as the petiole and veins of the leaf are discolored with several narrow, elongated, brown streaks; the leaflets are small, wrinkled, and cupped downward. Their surface is spotted with numerous small black lesions similar in shape and color to those already described but smaller in size. All the parts above ground are extremely brittle and the plant in many instances dies at an early age. The tubers produced by such a plant are usually no larger than marbles. This extreme dwarfing effect of the disease tends toward its self-elimination and is probably responsible for its comparative rarity.

### Cause

The disease can spread naturally from diseased to healthy plants although the means by which this occurs is unknown. Certainly, the transmitting agent is not an active one because ordinarily only a very few plants become infected in the presence of a diseased one. Infection has been obtained in about twelve days with artificial inoculation made by applying juice from a streak plant to the bruised surface of healthy leaves. No organism has ever been demonstrated to cause the disease although bacteria have been found in affected tissue. Some investigators incline to the view that this is a virus, or degeneration, disease.

### Control

It does not seem necessary to attempt extensive measures for the control of a disease that occurs so infrequently as this one. It is desirable, however, to take the precaution of removing affected plants from seed plots or from fields grown for seed.

### SPINACH LEAF

"Spinach leaf" is the term applied to a condition of the leaves of potatoes in which all or some of the leaflets have coalesced into one blade. This condition has been observed in New York State only on the Green Mountain variety. It has been found on plants coming from tubers grown in Wisconsin, Maine, and Ontario, as well as from native stock.

It was observed first about ten years ago and has been seen every year since. Although commonly found, the very dwarfed plants are not numerous. This condition apparently is similar to one described from Maine as a mutation.

The affected leaf is not smooth but is more or less puckered; the midrib is wide, apparently due to the coalescence for a distance with the midveins of the leaflets. Sometimes the puckering is so pronounced that the leaves resemble in form those of savoy cabbage. Some plants have all their leaves affected and are dwarfed so that they yield poorly, while other plants may have only the lower leaves deformed. Usually the latter plants are larger and may show no dwarfing whatever. Sometimes plants that show the symptoms when young subsequently produce normal leaves and a crop equal to healthy plants. There is never any yellowing or dying of the foliage as a result of spinach-leaf affection.

Tubers from dwarfed plants produce both normal and spinach-leaf plants. Tubers from affected plants, especially those showing dwarfing, should not be used for seed purposes. The abnormal plants can easily be eliminated from the seed plot.

## LEAF AND STALK DISEASES

### LATE BLIGHT

(Caused by *Phytophthora infestans*)

Late blight, the widespread and destructive disease of the potato, occurs on a few other kinds of plants, for the most part on species of the genus *Solanum*. What has been thought to be the same disease on tomato has been shown to be due to a different strain of the same pathogene. The strain that causes blight on the potato does sometimes spread to the tomato plants resulting in considerable damage.

Most varieties of potatoes are susceptible to this disease, particularly the Green Mountain type. Blue-sprout varieties, as Rural New Yorker, Sir Walter Raleigh, and others of that type, while rather susceptible, sometimes escape this disease as a result of their upright habits of growth. A few foreign varieties, as the Royal Kidney of England and the Professor Wohltmann of Germany, have been shown to be the most resistant of the many varieties tried. These resistant foreign varieties have proved unsatisfactory for American markets. A long red variety known locally as Evergreen is also fairly resistant and, although of excellent quality, has an undesirable shape and color.

This disease as it occurs in the vines is most commonly known as late blight or blight. It also is known as Irish blight, downy-mildew, and in

Tasmania as brown rust. On the tubers, the disease is called rot, dry rot, or mahogany rot.

The disease undoubtedly first appeared in South America which is the native home of the potato. Records as early as 1571 indicate losses due to it during damp cool weather. Although the potato was introduced into Europe in the sixteenth century, it was not until sometime between 1830 and 1840 that the blight appeared there or, at least, that any notice of it was taken. In 1842 the first scientific study was made of this blight as it occurred in Germany. By 1844 it had spread throughout the potato-growing sections of Europe, reaching its culmination in 1845. It was so disastrous in Denmark that meetings were held to discuss the calamity. It was the cause of widespread famine, especially in Ireland where about a quarter of a million people, dependent upon the potato for food, died as a result of its destructiveness.

In this country the disease appeared near Boston in 1842 and in the vicinity of New York City in 1843. By 1845, it had swept over the potato-growing sections of the United States and Canada, being most severe in Nova Scotia and New Brunswick. Since then it has occurred in all the potato-growing countries of the world. In the United States the disease is most prevalent and destructive in the northern and northeastern States but also at times is responsible for considerable loss in nearly all the eastern seaboard States even as far south as Florida, and along the Pacific Coast. It is not of great importance in the other southern States and in the central States.

In addition to the epiphytotic of the disease in this country during 1844-45, it has been reported as severe, particularly in the northeastern States, in 1898, 1901-05, 1912, 1917, 1919-20, and 1925. In localities, like northern Maine and eastern Long Island, where moisture conditions are favorable every year for its development, the disease appears each successive year with more or less severity.

The economic loss is very great in years when the disease is prevalent. But very few figures have been obtained to show the monetary loss as this is difficult to determine. When blight is generally destructive, prices usually rise, so that growers, losing half or more of their crop have had this made good, in part at least, through the increased price they received. Nevertheless the loss is real, sometimes amounting to one-third or more of the total crop of a State. The loss in New York State due to blight in 1903 has been estimated at \$10,000,000. In 1917 the estimated loss for the United States was 24,603,000 bushels and in 1919 it amounted to 20,978,000 bushels.

### Symptoms

Late blight rarely appears on the foliage of the potato plant before the blossoming stage. It may be noticed first as purplish or brownish black areas on the blade of the leaf (figure 12) or even on the leafstalk, flower-



FIGURE 12. LATE BLIGHT ON POTATO LEAFLETS

pedicels, and the stem. Usually the lower leaves are the first to become affected. The diseased areas have a water-soaked zone about their margin indicating the location of the advancing fungus. This invaded area becomes lighter colored than the normal green of the leaf, appearing as a light-colored halo about the blackened area, and in turn it blackens and dies. In dry weather, the destroyed tissue curls and shrivels, but, if moist weather prevails, it becomes limp and soon decays giving off a characteristic odor. If a blighting leaf is examined in moist weather, one will observe on the underside, rarely on the upper, a delicate mildewy growth about the border of the affected area. This is very characteristic of the disease and will enable one to distinguish it from other diseases with which late blight may be confused.

When the weather remains moist, the disease spreads over the plant with so great rapidity that a leaf may be destroyed in from one to four days after the spot first appears and the entire plant may die within a week. Instances are known in which entire fields that appeared healthy one day were dead the next. This condition, however, was due to a

previous infection that had escaped notice. Usually, after the first infections have taken place, the disease appears as spots in the field within which the plants are badly affected.

After the tops have blighted, varying percentages of the tubers begin to show decay. This first appears on the upper side as small purplish or brownish discolorations of the skin but later spreads over the surface so that large areas of the tuber may become involved (figure 13). If the

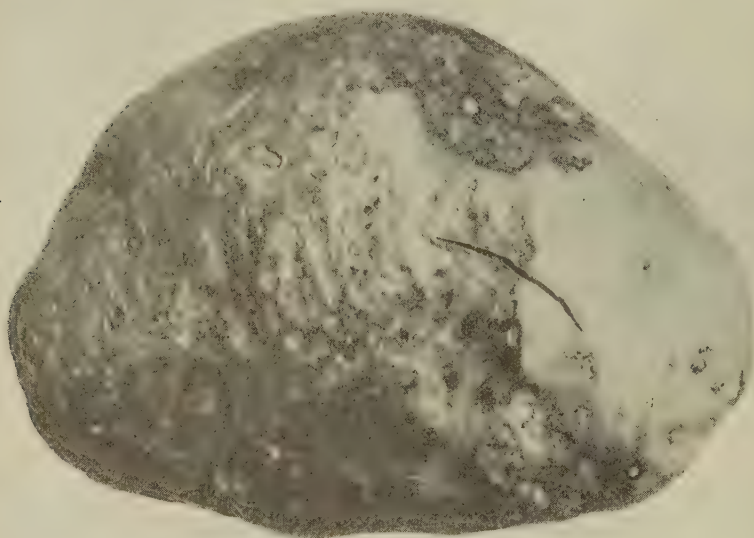


FIGURE 13. LATE-BLIGHT TUBER ROT

soil is comparatively dry, "dry rot," as the disease is known, extends not more than one-eighth or one-fourth of an inch into the flesh and the affected parts becomes somewhat sunken because the dead cells dry out. Tubers having small affected areas sometimes are overlooked at harvest and are put in storage, where the dry rot continues to develop during the first month or two or until cold weather lowers the temperature of the storage place. If, however, the soil is wet and warm at the time infection occurs or thereafter, the invaded tissue softens and this "wet rot" or "soft rot" extends to the interior so that the entire tuber becomes transformed

into a soft ill-smelling mass. This condition is brought about by the secondary invasion of bacteria and fungi.

### Cause

Late blight of potatoes has for many years been known to be caused by a fungous parasite, a downy mildew named *Phytophthora infestans*. This fungus is able to live over winter in the affected tubers as mycelium. It forms abortive sexual spores (oospores) on the surface of the tuber when aerial mycelium is produced. These oospores occur only rarely under natural conditions and even in culture media, and are probably not a factor in the wintering of the fungus. Experiments indicate that the mycelium of the fungus does not live over winter in the soil or in the old affected vines.

It is well known that infection can occur in the field from planting diseased tubers. If such tubers are planted in a warm wet soil, they usually decay; if planted in a dry soil, the growth of the fungus is retarded; but, if the planting is made in moist soil having a temperature of from 70 to 80° F, the fungus grows rapidly over the surface of the tuber and infects the sprouts in from four to twenty days. Sprouts from eyes nearest the lesions on the tubers are first infected. The fungus grows up the sprout and produces spores on it at the surface of the soil and even below ground. When the sprouts are infected early in their development, they usually become discolored and decay before reaching the surface of the ground. Under favorable conditions for the development of the fungus this decay may occur rather generally, resulting in a poor stand if many diseased tubers are used for planting.

When the conditions are not favorable for the development of the pathogene, the sprouts from infected tubers may appear above ground and develop into healthy shoots. It is possible even then for them to become infected sometime during their early growth from the fungus in the tuber, for it is known that the mycelium is able to remain alive in the seed piece for forty-five days after planting.

Infection of healthy vines above ground may take place from the spores produced on the surface of affected sprouts that have survived. Such sprouts are usually dwarfed and are more or less concealed by the growth of healthy shoots from the same hill. Spores produced on these shoots under moist conditions are easily detached from the stalks bearing them and some are very likely to be carried by air currents to near-by leaves or shoots. Here, in the moisture present, they germinate by the emergence of a dozen or more very small bodies called zoospores, each with two flagella. These zoospores swim about for a time, finally settle

down on the surface of the leaf, and send out a germ tube which is able to penetrate the epidermis of the host tissue. By continued growth this germ tube develops into a mycelium which spreads rapidly between the cells of the leaf. Thread-like suckers extending from the mycelium penetrate the cell and extract nourishment from it. The cells die one after another with the advance of the mycelium and appear, from the outside, as a dead spot, or blight, within five days after infection takes place. Branches of the fungus extend through the breathing-pores to the outside of the leaf and on these branches, or stalks, numerous spores are borne, which are capable of communicating the infection to other plants.

Epiphytotics of blight are able to start from a single infected plant in a field. The spores may be disseminated from the originally infected plant to those in the immediate neighborhood which in turn, under favorable conditions, become blighted in about a week's time. These blighted plants, occurring in one place, present the appearance of a circular or an elliptical dead or diseased spot in the field. Such areas indicate that an affected tuber had been planted within its boundary. If a considerable number of diseased tubers are used for seed, there may be many such spots in a field. Whether few or many, the disease will spread from them and destroy the entire field if weather conditions favorable for the development of the fungus occur frequently enough during the season.

Many of the spores fall to the ground. These are washed through cracks or holes in the soil to the tubers, where they germinate in the same manner as on the leaf. The fungus enters the flesh of the tuber, and by its growth produces the rot already described. The upper part of the tuber is more exposed to infection than is the lower part and those tubers nearest the surface of the ground are more likely to become infected than are those deeper in the soil. In certain light soils or sandy loams the spores are filtered out of the water, so that they do not reach the tubers unless the latter are near the surface. Infection of the tubers can readily take place after they are dug if viable spores come in contact with them. This commonly occurs if the blighting vines are not yet dead. The fungus does not live long in dead tissue.

The initial infection in a field is possible from sources other than the affected sprout. Spores may be produced underground on the surface of the invaded seed piece and on affected sprouts. It is not known definitely whether these spores make their way to the surface and infect the leaves that come in contact with the soil. It is known, however, that blighted tubers left in the soil may, during a mild winter, live over and produce volunteer plants the following spring and that these, becoming

affected, bear spores which may be blown to neighboring fields. The fungus may fruit on affected tubers thrown on a dump pile or on vines that come from such tubers, and thus such piles may serve as a source of inoculum to potatoes grown in the vicinity.

Moisture and temperature are important factors in the development and the spread of the late-blight organism. It has been pointed out already that the infection of the sprouts that come from planted tubers takes place most rapidly in a warm moist soil and that when planted in a dry soil, the sprouts may escape infection. The spores are produced and germinate only under moist conditions. Germination takes place readily at temperatures ranging from 40° to 50° F. and less frequently at temperatures up to 77° F., above which there is none. Once the fungus gains entrance to the host it spreads most rapidly in the tissues at from 70° to 80° F. It appears from these statements that infection will take place most readily under cool moist conditions, such as occur at night or on cool damp days, but that the vines are killed most rapidly at higher temperatures during what is commonly called "hot muggy weather." Records kept in Vermont over a period of twenty years have shown that if, at times during July or August, there is a temperature less than 50° F, if there is rain, and if these same conditions are repeated in a week or ten days, the blight begins to show at that time. The records showed also that rain and high temperatures and drought and low temperatures seem to retard the appearance of blight. It is a common observation that drought and high temperatures are unfavorable for the development of the pathogene and that, therefore, during hot dry seasons blight will not be troublesome. It is for this reason that blight is seldom a factor of importance in the southern and central States.

The blight organism is very persistent; so that, should weather favorable for its development occur later in the season, as in September, the blight will appear on the vines to some extent, followed by an infection of the tubers. Growers frequently have reported a rotting of the tubers when no blight was seen. This was due to a late infection of the vines that passed unnoticed. Development of rot in storage will not take place at temperatures below 40° F.

### Control

Since it appears that infection takes place by planting affected tubers it would seem that careful sorting and seed treatment would be helpful means of control. All affected tubers, as far as can be determined, should be discarded, for such tubers not only may serve as a source of inoculum but may rapidly decay after planting, thereby producing poor plants or none at all. Generally, treatment of the seed with hot water, hot air, and

various chemicals, has not given good results, although in some cases it has reduced the amount of infection.

Even if clean seed is used, the vines are not thereby protected against infection from diseased plants in neighboring fields. The application of a copper fungicide to the vines during the growing season is the only real safeguard. Bordeaux mixture is effective when applied thoroughly a sufficient number of times to keep the new growth covered. More recent experiments with a copper-lime dust has shown this material also to be effective. A detailed account of methods of preparing and applying these fungicides is given on pages 19 to 31.

If the vines are kept free from blight, there will be no tuber rot. It has been found that even when the vines blight the tubers can be prevented from rotting, to some extent at least, by throwing more soil over the hills. A heavy application of bordeaux mixture to the soil after blight has appeared has been reported as reducing the amount of rot. Blighted plants should never be dug until after the vines are entirely dead, for in so doing the chances of further infection are increased. It has, however, been reported that during exceptionally wet seasons early digging is desirable where the soil is low and wet, as under such conditions the fungus spreads rapidly on the tubers underground.

After the tubers are dug, they should be allowed to dry off before being placed in storage and all those showing any rot should be discarded. A dry cold storage will tend to delay the spread of rot on tubers. A temperature below 40° F. will prevent growth of the organism but it is said that a temperature below 38° F. will cause the tubers to sweeten. The disinfection of tubers before storage is of no practical value. Even the application of lime or of sulfur to the stored potatoes is a questionable practice.

### EARLY BLIGHT

(Caused by *Alternaria solani*) (Ex m) from plants.

Early blight occurs on potatoes, tomatoes, eggplants, and a number of other related plants. Such varieties as Early Rose and Early Ohio are very susceptible and most varieties may become injured to some extent. While a number of foreign varieties appear to be resistant, there are no American varieties of commercial importance possessing any considerable degree of immunity unless it is the McCormick, which is grown extensively in Maryland.

Early blight is the name usually applied to this disease although it is known as "leaf spot" and other less common names. While it does occur earlier in the season than late blight, it also is rather common late in the season when weather conditions are favorable for its development.

General attention was called to early blight in this country about 1892. It probably occurred much earlier but was confused with other leaf diseases. It is now known to be widely distributed in the United States, Europe, Asia, Africa, Australia, Bermuda, and Java.



FIGURE 14. EARLY-BLIGHT SPOTS ON THE LEAF

It is difficult to estimate the actual loss from this disease as it is often confused with flea-beetle injury and with late blight. Since early blight diminishes the effective leaf area, it is fair to assume that the yield is

reduced correspondingly. The wide distribution of the disease and its occurrence year after year is an indication of its large economic importance.

### Symptoms

Early blight is principally a disease of the leaves, occasionally affecting the stalks and the tubers. On the leaves it occurs as dark-brown or black, oval or angular spots which may show a series of concentric ridges that give them a target-board effect (figure 14). At first the lesions are small and sometimes remain so while the leaf is vigorous. After the leaf is weakened or dead, or even before, the spots may enlarge to a diameter as great as  $\frac{1}{2}$  inch. These areas normally appear first on the older, lower, and less vigorous leaves, and, under weather conditions favorable for their development, may be so numerous as to cause the leaf to die. The leaves above in turn may become affected and die, until finally there are only a few green spotted leaves remaining at the top of the plant. Lesions may likewise develop on the petioles and on the upper parts of the stalks.

Small, shallow, slightly sunken, more or less circular, decayed lesions are sometimes formed on the tuber. The margin of the diseased area is raised somewhat and the immediately adjoining skin of the tuber is slightly puckered. The lesion may readily be mistaken for a small bruise and is of no great importance within itself but frequently affords an entrance for saprophytic molds that complete the rotting of the tuber. This is true particularly if seed potatoes are shipped to Florida and other southern points where the high temperature is favorable for the growth of decay organisms.

### Cause

Early blight is caused by the fungus *Alternaria solani*. This fungus has a dark-colored mycelium on which large, club-shaped, dark-colored, several-celled spores are borne. These spores may be produced in either the upper or the lower surface of the affected area. The smaller spots do not bear spores but they are formed in great numbers on the larger spots. Nearly 1500 spores have been counted on a spot less than  $\frac{1}{2}$  inch in diameter. Three and four abundant crops have been produced from single spots. They may remain alive for a year and some have been found to be alive after seventeen months. They thus serve as an important means for carrying the fungus through the winter. The mycelium of the fungus also can pass the winter in affected vines and produce crops of spores the following spring.

The spores are disseminated mainly by the wind but it is believed that the potato beetle and perhaps the flea beetle may also carry them. Under

favorable conditions spores will germinate upon the surface of a leaf within an hour or two. Germ tubes are sent out from one or more of the several cells and may gain entrance to the leaf through flea-beetle or other injuries and are able to penetrate even the uninjured leaf. While the fungus only occasionally attacks the tubers directly, the early death of the foliage prevents the tubers from attaining the size of those of healthy plants.

A relatively high temperature with abundant dew or rainy weather and weakened plants bring about a condition most favorable for the production of spores and for infection. Less moisture and a relatively higher temperature is required by this fungus than by the late-blight fungus, so that epidemics of early blight may occur when late blight is absent.

### Control

Early blight is not as easily controlled as is late blight, but frequent applications of bordeaux mixture (5-5-50), beginning when the plants are young and continuing them at ten-day intervals throughout the growing period, will hold the disease in check and often control it entirely.

### TIPBURN AND HOPPER BURN

In early writings no distinction was made between tipburn and the various blights and even today many growers think that blight has struck their fields when tipburn is the trouble present.

Tipburn and hopper burn may be regarded, so far as their cause is concerned, as two distinct diseases, but, since the symptoms of the two are so nearly alike as to make identification difficult, they are discussed together in this article. Except when specifically stated, the term *tipburn*, as used here, will apply also to hopper burn.

All varieties of potatoes are subject to the disease, but Rural varieties are less injured than are Green Mountain and Irish Cobbler types; early varieties like Triumph and Early Ohio are very susceptible.

There can be very little doubt that tipburn is important if one considers the increases in yield obtained by spraying when late blight is not present. The amount of leaf area affected by tipburn indicates clearly that the reduction in yield caused by it must be considerable. It is more severe in the southern and midwestern late-potato-growing regions than in the northern, but prevails throughout the country when hot dry weather continues for a considerable period during July and August.

### Symptoms

There are two types of symptoms often included under tipburn. One type involves a sudden wilting of the tip and margin of the leaflets fol-

lowed by their collapse and death. This condition is more properly a "scald" that is brought about by an extremely high temperature following a period of abundant rainfall during which the foliage has expanded in rapid growth and the cells are turgid.

In the more common type of tipburn, there is a gradual dying and blackening of the tip and margins of the leaflet which is preceded by a slight yellowing of these parts. The affected area at the tip is V-shaped and, as it enlarges, it may involve a quarter of the leaflet. The affected area also proceeds backward from the tip along the margin of the leaf until half or more of the leaf surface has died. These affected margins roll upward and all the dead tissue becomes very brittle so that it frequently is broken, or torn. Usually the older leaves are much more susceptible than are the younger ones, while plants affected with degeneration diseases, such as mosaic and leaf roll, appear to be more susceptible than do healthy plants.

While tipburn directly affects only the foliage, the indirect effect is to reduce the size of the tubers and of the yield in proportion to the extent to which the foliage is injured. There is no evidence that such tubers are inferior for seed purposes to those coming from healthy plants.

### Cause

It has been rather clearly shown that tipburn may be caused by excessive transpiration. If the amount of water transpired is in excess of the amount absorbed by the roots, the cells of the tip and margins of the leaflets are the first to suffer through the presence of numerous water pores along their edges. The withdrawal of water from the cells bordering these pores causes plasmolysis and eventual death, unless the condition is relieved by rainfall or irrigation or by a reduction in temperature. If hot dry weather continues, the death of the marginal cells is followed by the death of the adjoining ones. Half or more of the leaf surface may be involved.

The leaf hopper *Empoasca mali* has also been shown to be a cause of tipburn or, specifically speaking, of hopper burn. The symptoms of hopper burn are similar to those already described for tipburn. These insects suck the juice of the leaf from the midrib and other veins, but the burning does not result from the mechanical injury or from the loss of sap but from a "specific" transmitted by the hopper. It has been found that an extract made from the crushed body of the hopper will, when injected into a healthy leaf, produce typical tipburn. A single insect is able to produce tipburning of one or more leaves, and the burning will result regardless of favorable temperature and moisture conditions for the development of the potato.

When it became known that the leaf hopper could produce tipburn, at once it was thought by many to be the cause of all cases of tipburn. Since it is now known that this trouble occurs at times in sections where leaf hoppers are not present, the relation of weather to the disease seems fairly well established. In localities where leaf hoppers are abundant, one may expect the development of tipburn unless the plants are protected.

### Control

Cultural practices that conserve soil moisture should be helpful in reducing the amount of physiological tipburn, but regardless of which factor is responsible for its development, the frequent application of bordeaux mixture will hold it in check. The application should be made throughout the season, using the formula as advised for the control of late blight. An excess of lime is often recommended (page 19). Dusting apparently has not proved to be an effective control measure.

### LEAF BLOTCH

(Caused by *Cercospora concors*)

Leaf blotch was observed first in this country in 1905 when it was reported from Vermont as causing some damage to the foliage. What appears to be the same disease has occurred in Europe for many years and has been reported from Germany, Russia, and adjacent countries. It rarely has been observed in the United States and certainly is not severe enough to cause alarm. It apparently occurs only on potatoes and is said to be more severe on early than on late varieties. As the fungus causing leaf blotch is favored by moist cold conditions and is checked by dry hot weather, it is believed that the disease will occur more commonly in the northern potato districts.

### Symptoms

The spot, or blotch, begins to develop while the leaf is still green but does not affect the vines severely until they have begun to weaken. The spots blacken and the affected leaflet usually becomes yellow and dies. The fruiting bodies of the causal fungus show upon the living leaf as indistinct pale or violet-gray spots on the lower surface of the leaf. This is indicated on the upper surface by a light-colored area. As the fungus develops the areas blacken and die. The fungus may also fruit on the upper surface.

### Cause

Leaf blotch is caused by the fungus *Cercospora concors*. Thin-walled, nearly colorless, one- to several-celled spores are borne singly on brownish

stalks that grow in tufts through the stomates from the mycelium in the affected areas of the leaf. These spores are blown to other leaves and soon germinate in the presence of moisture, the germ tube entering the leaf through the stomates. After the fungus has developed to some extent in the leaf, the tissues die and the dead area appears as a spot or blotch. Later thick-walled spores, chlamydospores, are produced and these probably carry the fungus through the winter.

### Control

The disease can be controlled by spraying with bordeaux mixture as is done for early or late blight.

### ARSENICAL INJURY

Brown dead spots may be produced on the foliage by soluble arsenic present in the poison applied as an insecticide. These spots often resemble those of early blight. Usually the spots surround a wound, such as a flea-beetle injury, through which the poison is able to enter the leaf. Not uncommonly large leaf areas are killed by the application of paris green to foliage that has been injured by the potato beetle. Sometimes the damage done by the poison is greater than that by the bugs. The accumulation of poison in the axils of the leaves is reported to cause injury to the stalks or to the growing tips of shoots.

This injury may be prevented by the use of lime with such poisons whether applied as a spray or a dust. When added to bordeaux mixture, an arsenical will cause no injury to the plant.

### FROST NECROSIS OF FOLIAGE

Everyone knows that frost will kill potato vines and is familiar with the blackened and dead condition of frosted vines and with the brown scalded appearance of the tender tops when "touched" by frost.

A peculiar condition of the foliage due to frost has been reported from Colorado, but has not been generally recognized elsewhere although it may occur generally. This condition consists in the presence of numerous small, irregular, dead areas, usually less than a millimeter in diameter, along the midrib near the basal part of young leaves. The larger dead areas extend through the leaf but the microscope reveals many smaller ones extending from the upper surface to the vessels below. This spotting, rarely, if ever, occurs on old plants, but often is observed on potato plants during the early growing season.

The injury is ascribed to freezing which occurs when the cells are turgid and the stomates themselves are filled with water. Even though the air temperature is well above 32° F., under the above conditions the temperature of the cells about the stomatal region is reduced to the freez-

ing point when rapid evaporation of moisture takes place. In one observation made, succulent, young, healthy plants in pots were kept in a warm basement over night and in the morning were placed outside in an air temperature of 39° F. when the humidity registered 45 per cent and a light wind was blowing. There was a depression of 7.5° F. on a wet bulb thermometer on a reading made at the time, which would give a temperature of 31.5° F. The injury resulting could not be observed until eleven days later. During early June warm nights, followed by very sudden cooling in the early morning, often occur and during such times this type of injury may take place.

### RHIZOCTONIA

(Caused by *Corticium vagum*)

Rhizoctonia is a name applied to one of the most common potato diseases. Not only does it occur on potatoes but it also affects beets, sugar beets, carrots, lettuce, asparagus, beans, rhubarb, cabbage, celery, cauliflower, clover, alfalfa, cotton, carnations, and many other kinds of plants including weeds and field, vegetable, ornamental, and floricultural crops. There seems to be no variety of potatoes that is resistant to it, although in Maine it has been observed that the Irish Cobbler is affected more severely than is the Green Mountain variety.

The term *rhizoctonia* is derived from the generic name of the fungus causing the disease. While this term may be applied to any form of the disease on any plant, there are, also, many other terms used to designate particular symptoms; such as stem canker, brown stem, stem rot, collar rot applied to the lesions on the sprouts, rosette disease sometimes applied to affected vines, and rhizoctonia scurf or scab, russet scab, and dry core applied to types of injury or markings on the tuber.

Rhizoctonia was first described in 1858 from Germany. It is now known to occur in various European countries, in India, Australia, Tasmania, West Indies, North and South America, and probably wherever potatoes are grown. In the United States it has been reported from many States and especially from all important potato-producing sections.

It is difficult to determine the extent of the damage resulting from this disease; but in the aggregate it must be considerable, resulting as it does in poor stands, reduced yields, and to some extent in undesirable tubers. The damage in any one field usually is not very great, although some fields have been seriously affected and the loss in a given region may be greater some years than others.

### Symptoms

The first appearance of the disease is on the sprouts where brown, sunken, circular or elongated spots, or cankers, may appear before the



FIGURE 15. RHIZOCTONIA CAUSES A CANKER OF THE SPROUTS

plant has pushed through the ground (figure 15). These cankers may girdle the young stem so that the part above dies. Sometimes one or more other sprouts start from below the injury and may develop into vigorous vines if there is plenty of food material available in the tuber and if the new sprouts do not likewise become affected. In the latter case a third set of sprouts may develop, but they are spindling and rarely attain a vigorous growth. They may be so weak that they do not appear above ground or they may become affected without further growth taking place. In a field where these conditions occur there may be vigorous, healthy-looking plants; others that are only half as high; some that are weak and spindling; and vacant places where the plants have failed to appear. Cankers may also occur on the stolons, cutting the tuber from the main stem and thus preventing the further development of the tuber.

Cankers occasionally develop on the stems of older plants but they do not extend so deeply into the interior as to destroy the parts above. These cankers show at or below the surface of the soil as irregular, elongated, brown areas. They may be rough or shaggy and sometimes girdle the



FIGURE 16. RHIZOCTONIA CAUSES AERIAL TUBERS

stem. Such cankers interfere with the movement of the elaborated food material to the roots and tubers and thus suppress their normal development. The vines become yellow or reddish yellow; the leaves have a tendency to roll due to the accumulation of food above the canker; the stalks become swollen, especially at the nodes; and the buds enlarge sometimes to the size of small tubers, giving rise to the term *aerial tubers* (figure 16). This term also applies to the numerous, small, irregular tubers produced on short stolons at the surface of the ground when cankers on the main stem or on the stolons below ground prohibit normal tuber formation.



FIGURE 17. RHIZOCTONIA CANKERS ON THE TUBER

Even the regularly formed tubers may become affected in various ways with the disease. Discolored areas may extend from the stolons to the stem end and then gradually involve the entire basal end of the tuber.

Brown streaks are formed extending from the point of attachment of the stem into the flesh for a short distance. The skin of the tuber may become russeted, sometimes badly so, or injured to the extent of forming deep cracks over the exposed flesh of which a corky layer develops.

Another type of injury to the tuber is designated *dry core*. A sunken, circular area of dead cells develops about some of the lenticels. These areas may become nearly as large as the end of a lead pencil and extend into the flesh an equal depth, although commonly they are smaller (figure 17). Usually a canal or pore extending inward develops in the center of this core resembling the injury caused by wireworms. This core of diseased tissue may be picked out of the tuber leaving a thimble-shaped depression.

Some observers have associated the disease with a rotting of the seed piece and even of the new tubers; but this certainly is not general, if it occurs at all.

### Cause

The disease is caused by a fungus *Rhizoctonia solani* (= *Corticium vagum*) which is able to live for a long time, even in dry soil. The fungus also is able to live from season to season on perennial plants. On the potato tuber as on other hosts, the fungus in the fall forms little masses of white mold which, after a time, become transformed into hard, black or brown, flattened bodies closely adhering to the surface of the tuber. These bodies, known as *sclerotia* (figure 18) or scurf, are made up of closely interwoven fungus filaments. They vary in size and shape, some being smaller than a pinhead and others as large as the half of a pea seed. They may be numerous on the surface of the seed or only a few may be present. By persons not familiar with them, the sclerotia may be mistaken for black soil adhering to the tuber. Unlike soil they cannot be washed off although they may be scraped off easily with the finger nail. They serve to carry the fungus over winter and to disseminate it. Scarcely distinguishable brown filaments of the organism sometimes occur, adhering closely to the russeted or cracked surface of the potato.

When such tubers are planted in a warm moist soil, a fine, white, moldy growth develops from the sclerotia. When the filaments of this growth come in contact with the sprouts or with the stolons, they penetrate the tissues, producing the brown sunken cankers already described. Older stems are attacked in the same manner but the pathogene is unable to penetrate as deeply. Brown strands of the fungus similar to those

formed on the tuber may be found over the lesions on these older stems. When moist conditions prevail continuously around the plants, there occasionally develops from such brown strands a grayish white layer on the lower part of the stem sometimes extending a few inches above the surface of the soil and even out on the leaf stalks of the lower leaves.

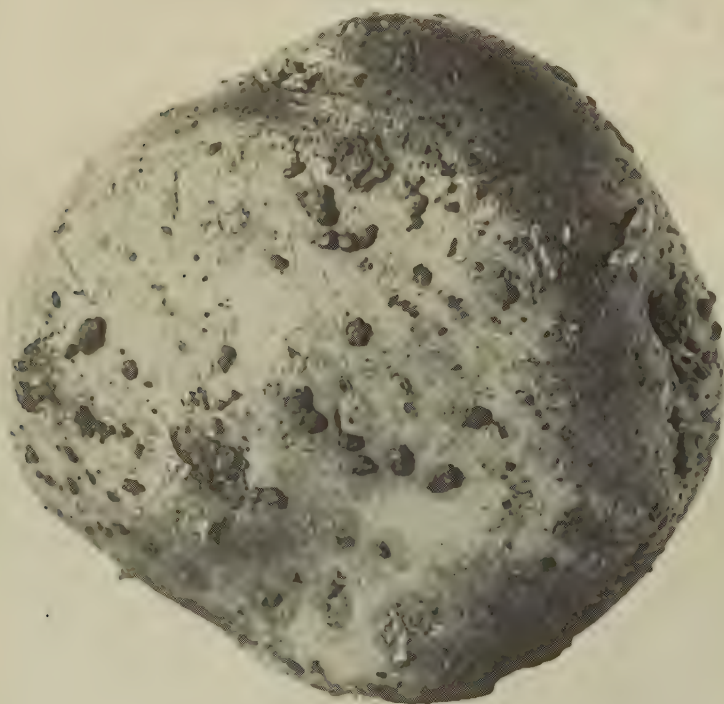


FIGURE 18. TUBER WITH LARGE SCLEROTIA OF RHIZOCTONIA

This growth is attached loosely to the host and is very evanescent, disappearing soon after the plant is pulled up or upon the arrival of sunshine. This is the fruiting layer and on it are borne the spores of the perfect stage which aid in the dissemination of the fungus.

The life history of the fungus has not been worked out completely but it is almost certain that the organism is able to exist for a long time in the soil as a saprophyte, where it attacks its hosts, and, if the environment is favorable, infection takes place.

Opinions differ regarding the soil and weather conditions most favorable for the growth of the fungus and for its attack on the potato. Some claim that a heavy wet soil is most favorable, while others find most abundant growth in a light aerated soil. An acid condition of the soil is evidently best suited for the growth of this fungus although in culture it grows well in an alkaline medium. Careful observations and experiments indicate that greatest injury to the sprouts occur at temperatures below 70° F. but that lesions may be produced at any temperature from 48° to 80° F. if other conditions are favorable for its growth. If conclusions are to be drawn from all observations made, they would be that the fungus will grow and cause injury over a wide range of soil and weather conditions.

### Control

As this organism is able to live from year to year in the soil and can live over winter as sclerotia on the surface of the tuber, one must give consideration to both these conditions in undertaking any control measure. It is difficult to eradicate the pathogene in the ground or to apply any substance that would protect the plants. The application of lime has been claimed by some to reduce the amount of injury but such a practice would encourage the development of scab. Soil sterilization while effective is impracticable. Rotation in which potatoes and other susceptible plants are kept from the soil appears likewise to be impracticable as there are so many plants susceptible to the disease. In some localities even new land gives a higher percentage of affected plants than does land that has been under cultivation for some years.

It has been observed that a greater percentage of sprout injury and missing hills results from planting affected tubers than when using healthy ones. This suggests that the attack from the fungus in the soil is slower than from that on the tuber. The use of healthy or disinfected seed, therefore, is a control measure that promises much success, and for this reason seed treatment is urged (pages 6 to 14). Any handling of the seed tubers or soil manipulation that will hasten the appearance of the sprouts after planting lessens the amount of damage from the disease.

## WILT

(Caused by *Fusarium oxysporum* and by *Verticillium albo-atrum*)

As the symptoms produced by each of the two potato-wilt parasites are so similar as to be indistinguishable to most persons, the diseases caused by them will be treated together in this paper under the one name.

Many kinds of plants are affected with wilt diseases and apparently in some cases there is a relation between them and potato wilt. Some investigators claim that the tomato and a few other plants are invaded by the potato *Fusarium*, but this does not appear to be common out-of-doors. All varieties of potatoes seem to be about equally susceptible. The disease is also known as *Fusarium* blight, vascular mycosis, stem blight, and stem-end browning.

What is supposed to be this disease was first observed in Illinois in 1895 and in New York State in 1896. It is now known to occur throughout the United States wherever potatoes are grown. The *Fusarium* wilt is more prevalent in the southern sections, although it is often severe in the northern States in hot seasons, while the *Verticillium* wilt occurs most commonly in the northern States. *Fusarium* wilt also occurs in Europe, where it is said not to be severe, and in Hawaii.

Very heavy losses in the United States are reported to be due to this disease. Some fields in 1915 showed as high as from 70 to 80 per cent



FIGURE 19. A WILTED PLANT COMPARED WITH A HEALTHY PLANT

of plants affected. One writer claims that in 1917 it caused a loss of 4.54 per cent of the crop, or of 25,000,000 bushels. It was very prevalent and severe in New York State in 1914, 1918, and 1921. Losses from the disease are due to premature death of the vines, and to the tubers being less marketable for consumption and for seed.

### Symptoms

Some vines first show evidence of the disease at about blossoming time or earlier if infection takes place from affected seed tubers. Such vines have a more spindling growth than do healthy ones and have a yellowish green color. There may also be some curling and rolling of the leaflets (figure 19) and tipburning. Such vines die prematurely while the stalk remains upright, except for the tip which may droop. Vines from healthy tubers show the first signs of the disease some time after blossoming and often as late as August. The lower leaves of affected vines turn yellow, drop to the side of the stalk, and die. This should not be confused with the yellowing of the lower leaves that takes place from shading when there is a vigorous growth of vines and especially when these conditions are accompanied by prolonged cloudy weather. The yellowing and dying of the leaves in the case of this disease proceeds from the base upwards until there is often only a cluster of green leaves at the top. On hot days this yellowing is preceded by a wilting of the leaves and even of the stalk. Sometimes only one stalk may be affected but more commonly two, three, or all the stalks show the symptoms. When large vines are affected severely they may become more or less prostrate.

A different symptom of wilt has frequently been observed in which the young top leaves wilt and die before the lower ones. They have the appearance of being scalded. All doubt may be dispelled, however, by cutting away the bark at the base of the stalk. If the woody tissue beneath is brown, the disease is wilt; for healthy tissue has a white or a faint yellow color. This brown color may extend all the way around the stem or may be confined to one side.

Badly wilted plants pull much more easily than do healthy ones. Even in the fall after the death of all plants this is noticeable. It is due to the rotted condition of the roots. All the fine feeding roots and the bark of the larger taproot become entirely decayed. Such affected roots cannot properly perform their function of absorbing water and soil solutes, and the vines wilt and die as a result. It is likewise because of this weakened condition of the roots that they are unable to support the large vines which fall over.

Tubers from affected plants may show a brown or black discoloration

of the vessels. As this occurs at the stem end, it commonly is known as stem-end browning. Similar discolorations may sometimes be due to chilling or to unknown causes. The vessels diverge from a point to which the stem, or rhizome, is attached to form a ring about a quarter of an inch below the surface throughout the length of the tuber, so that when the vessels are affected, successive slices across the tuber from the stem end will show this discoloration (figure 20) first as a browned area then as a ring or a part of a ring. Sometimes the finer vessels extending into the flesh are also discolored, giving the appearance known as net-necrosis.

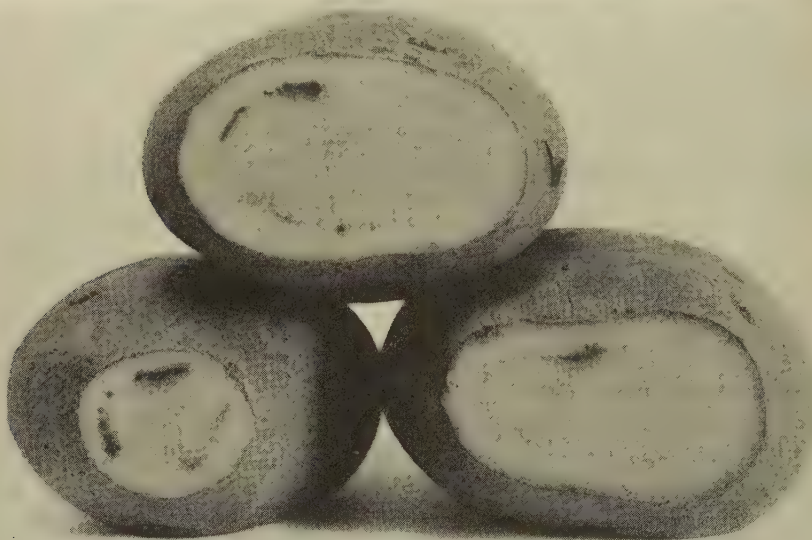


FIGURE 20. WILT TUBERS SHOWING A RING OF STEM-END BROWNING

Occasionally growers confuse the natural straw color of the vessels of some varieties with this disease, but when once the brown or black color is observed there will be no difficulty of identification. It must be said, however, that sometimes the natural discoloration of the rhizome in dying extends into the tuber for a short distance and this condition is difficult to distinguish from wilt discoloration.

The browning of the tubers from wilt may occur during their growth but at harvest it usually has not progressed more than a quarter or half inch from the stem end. It may continue to progress after storage until the browning extends from one end of the tuber to the other. Not all tubers from affected vines show stem-end browning. It is not unlikely that

the age at which the plant becomes affected is a factor in determining the percentage of tubers with vascular discoloration. There doubtless are other factors. Tubers that became diseased early in their development may exhibit a knob, or nipple, at the stem end (figure 21) instead of the normal

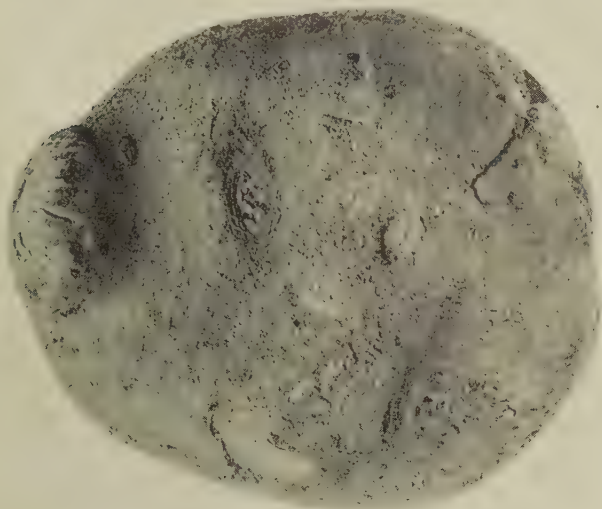


FIGURE 21. WILT TUBER SHOWING KNOB AT STEM END

depression at the point of attachment. Not all tubers free from browning necessarily are free from wilt. Tubers coming from wilted hills have been known to produce perfectly healthy progeny.

Several investigators believe that the *Fusarium* causing the discoloration also causes a decay of the tubers, while others believe that the rot occurring before or during storage is due to other organisms. Certainly browning does occur without decay even when affected tubers are kept until spring, and observation in this State seems to indicate that the wilt organism does not produce rot. There are, however, other indications of wilt than the browning. In late spring, affected tubers usually are much firmer than are healthy ones and bear small spindling sprouts as compared with the large stocky sprouts of healthy plants. It is reported that in certain cases of *Verticillium* wilt the eyes are killed to a greater or less extent.

### Cause

Two fungous organisms, *Fusarium oxysporum* and *Verticillium albo-atrum*, are known to cause wilt. Their life histories are very much alike and will be discussed together. These fungi are able to pass the winter in affected tubers and in the soil. Just how long they can live in the soil without potatoes is not known. It is believed that the *Fusarium* persists much the longer. In fact, cases are recorded of severe attacks in fields in which potatoes have never been grown. It appears to be less abundant in cultivated soil that has had no potatoes in the rotation than in soil that has not been disturbed. On the other hand, frequent cropping with potatoes appears to increase soil infestation.

These fungi enter the potato plant through the roots either directly or through wounds. The mycelium invades all parts of the root but in the stem is confined to the sap vessels. The *Fusarium* does not extend far above ground but the *Verticillium* will grow even to the top of the stalks and into the leaves. Both fungi enter the tubers through the rhizomes and discolor the vessels of the tuber. The *Verticillium* is believed to cause a more intense browning or blackening than does the *Fusarium*. *Fusarium* produces spores on the decayed roots and doubtless is disseminated to some extent by the washing of these spores. The *Verticillium* fruits abundantly on the diseased stalks, and the spores are probably blown about by the wind and thus contaminate new soil areas. While both fungi can exist in affected tubers and grow up into the sprouts, yet it is known that tubers of wilted plants may be discolored without the causal fungus being present. It is thought that the discoloration precedes the advance of the fungus and may be the result of injurious substances secreted by it or by diseased cells.

The *Verticillium* grows at lower temperatures than does the *Fusarium*. This is probably the important factor in their distribution. Both probably exist in most New York State soils. Each becomes predominant in those years most favorable for its development. It would seem that the *Fusarium* is the more prevalent in this State because wilt is most severe in the hot seasons.

### Control

These fungi living in the soil as they do and attacking the roots and invading the interior of stems and tubers cannot be reached by sprays or seed treatment. There are only two means of attacking them and both are only partially effective. One is to avoid the planting of affected tubers and the other is to reduce the fungus in the soil by a long rotation. While it may be possible by clipping the stem ends of tubers to discard discolored tubers, it cannot be depended upon to eliminate all. A better method is

to remove affected plants from the seed plot as outlined on page 35. When this is done thoroughly, there should be no need of stem-end clipping. Rotation will be helpful in reducing the infestation and one should also avoid distributing the refuse from diseased plants to the soil with manure or in any other way. Where the disease is particularly troublesome, some advantage may be gained by the use of early varieties which mature before the disease has made much headway.

### FUSARIUM WILT AND TUBER ROT

(Caused by *Fusarium eumartii*)

*Fusarium* wilt is known to occur occasionally on potatoes in New York and Pennsylvania and probably has a wider distribution. It causes marked reduction in the yield of affected plants and a stem-end decay of invaded tubers.

#### Symptoms

In general, the symptoms are similar to those given for wilt. Inoculated plants out-of-doors first show a leaf burning and sometimes a rolling or slight rosetting of the leaves. In late stages the leaves wilt and die. A dry rot develops in the stem and spreads upward sometimes as far as the lower branches and downward into the roots and tubers. At first affected tubers may show only a stem-end browning similar to that already described, but, no later than harvest, some or all of these show a sunken, wrinkled, dry stem-end rot (figure 22) which may proceed until the entire tuber is decayed. This rotting may also start from wounds made in the tuber and continue to develop in storage.

#### Cause

This disease is known to be caused by *Fusarium eumartii*, an organism closely related to the fungus causing the common *Fusarium* wilt and also to other *Fusaria* causing storage rot. Very little is known of its life history or of the conditions most favorable for its development. It is a soil-inhabiting organism and infection of healthy plants may take place in infected soil. It may possibly be carried over winter on affected tubers but this seems unlikely since these tubers usually become completely decayed. Spores are borne on the dead stems near the soil and on the rotted tubers and both serve to distribute the fungus to new territory. Transportation of infested soil and of affected potato vines and tubers doubtless serve to do this also.



FIGURE 22. *Fusarium Eumartii* CAUSING TUBER ROT

### Control

While no control measures have been worked out for this disease, it is evident that the measures suggested for the control of the common wilt should also be employed for this disease.

### BROWN ROT

(Caused by *Bacterium solanacearum*)

Brown rot has been reported as affecting a large number of plants including potato, tomato, pepper, eggplant, tobacco, ground cherry, black nightshade, petunia, salpiglossis, verbenas, cosmos, bean, peanut, sunflower, ragweed, and other plants. All varieties of potatoes appear to be susceptible.

The name *brown rot* has commonly been applied to this disease on potatoes in this country. It is also known as bacterial wilt, yellow blight, and, in India, as bacterial ring disease.

The disease is known to occur from Japan and the Philippines to New Zealand and west through Java, Sumatra, and India, to Australia and South Africa. In the United States it is found from Maryland and New Jersey to Florida and Porto Rico. Its northern and western distribution is not known but it probably occurs in the middle-western States, especially to the south, and occasionally has been found on Long Island and in one or two other southeastern counties of New York State. It is primarily a hot-weather disease and seldom occurs in the northern States. What appears to be the same disease has been reported from Russia, England, France, and Italy. The cause of the disease was discovered in 1895 and the first complete description was given at that time.

Very severe losses have resulted from the disease in the South where it is common. Cases have been reported from New Jersey where the entire crop has been destroyed. As its occurrence in New York is restricted in area as well as in frequency, it must be regarded as of minor importance in this State.

### Symptoms

Affected plants show a wilting and shriveling of the foliage and a drooping of the younger shoots. The vascular bundles become discolored and these may show on the surface as narrow dark stripes on the stems and leaves. The tubers also become affected and show a brown ring in the vascular tissues somewhat similar to the other wilt diseases. However, upon cutting across the affected tuber or the stalk, a yellowish white bacterial ooze issues from the discolored areas. Sometimes this discoloration will show on the surface of the tuber, especially at the stem end, as a dusky hue even when the skin is unbroken and the outer tissues are

sound. Saprophytic rot organisms frequently gain entrance to affected tubers and bring about a soft, slimy, ill-smelling rot.

### Cause

A rod-shaped motile bacterium called *Bacterium solanaccarum* is the cause of the disease. The organism gains entrance to the plant through wounds in the vines and probably more often through broken or injured roots. It also is able to enter through the stomates. It may be carried from plant to plant by the potato beetle. After gaining entrance, its growth is rapid and the disease symptoms may be evident in from eight to ten days or even in less time on succulent shoots. The bacteria invade chiefly the vascular bundles although they may be found in the soft tissues of the leaf and in the cortex and the pith of the stem. The walls of the cells are dissolved and cavities are produced. Succulent tissues succumb rapidly while older ones wither and die more slowly. The bacteria extend their growth from the affected vines into the new tubers and cause the diseased condition already described. It is believed that the bacteria exist in certain virgin soils of the South and penetrate susceptible plants through the roots and underground stems.

### Control

The disease does not cause sufficient damage in this State to require a consideration of control measures. A long rotation has been recommended, but, on the other hand, some Florida growers have reported that the disease diminishes with continuous cropping of potatoes. Control of the potato beetle may be helpful in preventing infection. Early harvesting, when practicable, may save a part of the crop of a field in which the disease has become widespread.

### BLACK LEG

(Caused by *Bacillus atrosepticus*)

Black leg has never been observed in New York on any plant other than the potato although it has been reported elsewhere to occur on tomatoes and on a few other plants. The most susceptible American variety is Irish Cobbler. It occurs to some extent on Green Mountain and other white-sprout potatoes, but it has seldom been observed on blue-sprout varieties. It is known by various names as stem rot; basal stem rot; black stalk rot; black stem; bacterial black rot; tuber rot; and most commonly black leg, meaning a blackening of the base of the stalk.

The disease was prevalent in European countries for many years before it was observed in the United States and Canada. All indications point

to its introduction into America on shipments of potatoes from Europe. It was first definitely recognized in this country at the Vermont experiment



FIGURE 23. EFFECTS OF BLACK LEG ON POTATO ROOTS AND STALKS

station during 1906 and was found in Maine the following year. Now it occurs in all potato sections of the country but is not regarded to be as serious as are some other diseases. A very considerable loss may result from this disease when it once becomes prevalent in a field, so that precautions should always be taken to hold it in check. It may be responsible

for missing hills because it destroys the sprouts before they appear above ground or causes the seed piece to rot before sprouts have started. Affected vines yield smaller tubers than do healthy plants and some of these usually become affected and unfit for market.

### Symptoms

Black leg when observed in the field at about blossoming time can easily be recognized by the yellowish color of the foliage; by the erect stark appearance produced by the upward rolling of the leaflets, usually all of them being thus rolled; and especially by the blackening and rotting at the base of the stalk (figure 23). It may be necessary to pull up some of the stems to notice these latter symptoms. Later in the season the black rotted condition may have extended for a considerable distance up the stalk and even into the leaf petioles. By this time the stalks have fallen to the

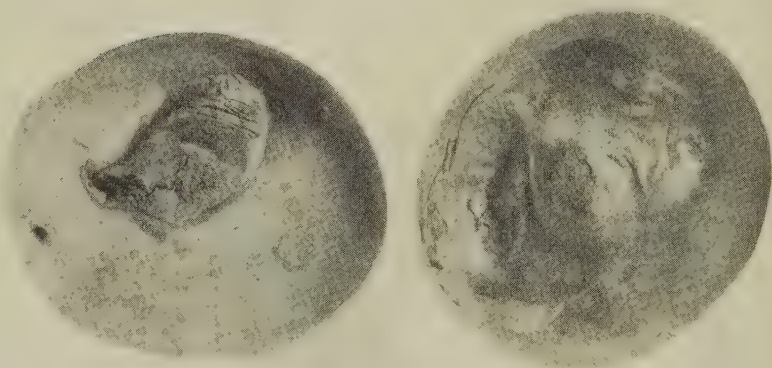


FIGURE 24. BLACK-LEG TUBER ROT

ground and the leaves and stems gradually die. When the affected plant is not killed quickly, the stems may become somewhat thickened by the accumulation of starch and aerial tubers may be produced in the axils of the leaves as also happens when the stem is injured by *Rhizoctonia* (page 73). In most cases only an occasional plant is affected and this stands out clearly in contrast to the green foliage of healthy neighbors.

Sometimes only a part of the vines show the disease, the others apparently being healthy.

Tubers from affected plants may show dark areas at the stem end when it is cut away and these may extend to a soft rotted condition further within the tuber. Usually the tubers will show a black or brown or sometimes a light-colored stem-end rot (figure 24) more or less soft at first but becoming firm and shrunken on drying. This rot of the tuber is not always confined to the stem end but may sometimes be observed even at the eye end. The rotted area may be sharply set off from the healthy part by a dark line. A liquid exudes in time from the badly rotted tubers causing the soil to stick to them. The white flesh of the rotted part when exposed to the air rapidly turns black. During the progress of the disease the flesh of the tuber becomes transformed to a soft, black, foul-smelling mass, caused by an accompanying soft-rot organism or by saprophytes.

### Cause

For a time it was thought that the disease might be caused by more than one organism, as investigators gave different names to the bacterium which they proved to be capable of producing the trouble; but more recent studies have shown these various organisms to be identical. The name *Bacillus phytophthorus* has been used but more recent study indicates that *Bacillus atrosepticus* is the first name properly applied to the pathogene.

This bacterium does not live over winter in the soil and is transmitted mainly, if not entirely, by means of affected or contaminated tubers. It readily is killed by drying, so that it probably is not able to live very long on the surface of uninjured tubers unless it lodges in cracks of the skin where moisture is available. Healthy tubers may become inoculated when the rotted tissue of affected ones becomes smeared over their surface. It is believed that healthy tubers may also become inoculated at cutting time by their cut surfaces coming in contact with those of affected tubers or with a contaminated knife. Tubers invaded by the black-leg organism have been known to decay rapidly when kept under warm moist conditions, as when piled together in masses. It has been reported that before harvest in wet autumns the parasite may enter the tubers through the lenticels from contaminated soil and cause a wholesale rotting of the tubers.

Warm moist weather is most favorable for the development of black leg, while hot dry weather is unfavorable. Although it has been reported as being most severe in low wet areas in a field, it, nevertheless, occurs on light well-drained soils if the soil is moist and warm and affected tubers are used in planting. If affected tubers are stored in a warm moist storage house, the disease continues to develop until they are entirely decayed.

### Control

To insure freedom from black leg one should plant only tubers from the fields in which the disease has not occurred. Where one grows his own seed, a seed plot should be maintained from which all plants affected with black leg should be removed as soon as observed (page 35). If one is uncertain about the source of his seed, the tubers should be treated in order to prevent infection from those possibly contaminated (page 6). While cutting tubers, not only should all discolored and rotted tubers be rejected but the knife should be disinfected. This can easily be done by having more than one knife available for each seed cutter. When a knife has been used in cutting a rotting tuber, it should be placed in a strong solution of formaldehyde (1 tablespoonful to 1 pint of water) until needed again. If these precautions are taken, the loss from black leg even on susceptible varieties will be negligible.

## TUBER DISEASES

### COMMON SCAB

(Caused by *Actinomyces scabies*)

Common scab is a well-named disease of potatoes because it is found commonly in most potato-growing regions and because the appearance is somewhat similar to the incrustation formed over a sore or a wound on the skin of man and animals.

While this disease appears mostly on potatoes, it has also been reported on the roots of beet, mangel, turnip, rutabaga, radish, cabbage, carrot, salsify, and parsnip. Some investigators think that it is confined to the potato, beet, and turnip. No very careful work has been done to prove this point and it is possible that the scabby appearance on these various plants is due to different varieties or species of the organism.

From the work that has been done on varietal resistance of potatoes, it is apparent that there is a difference of opinion among investigators. Some believe that there is no variety that is markedly resistant to scab, while others find the russet varieties considerably more resistant than are the smooth-skinned ones and that the white-skinned varieties are most susceptible. It has been reported from New Jersey that American Giant does not scab to the same extent as does round stock, although not immune by any means. Early varieties are thought to have more scab than late varieties, for they mature in the hotter part of the season when the temperature is more favorable for the development of the scab organism. It is thought by some that thickness of skin is correlated with resistance and that the character of the lenticels may also be a factor, those varieties with close textured lenticels being the more resistant.

Many different names have been given this disease, as pox, scurf, mange, brown scab, corky scab, callosities, and actinomycoise, but the term "common scab" is more generally used than any other. The terms "deep scab" and "shallow scab" are used to indicate the depth of the lesion but it is uncertain whether the two types of lesions are caused by an identical organism.

The first written account of scab appeared in an English encyclopedia of agriculture in 1825 and many accounts of it have appeared since that time. But as there are several kinds of scab on potatoes and as the early descriptions are not very clear, it is not certain what scab is meant. The common scab occurs generally in nearly all potato-growing regions of Europe and America, so it is not unlikely that some of the early descriptions refer to it. It was not until 1890 that the cause of scab was determined. At this time, two American experiment-station workers reported this fact as a result of their work.

While there is some evidence that the use of scabby tubers in planting results in decreased yields, the principal loss from the disease is due to the unmarketability of badly scabbed tubers and to the reduced value of those more moderately affected. Scabbiness gives an undesirable appearance to tubers, and, when potatoes are pared, there is a loss due to the necessity of paring deeper than if they were smooth. The U. S. No. 1 grade, which is being adopted generally throughout the country, requires that potatoes be free from scab and allows but a 6 per cent tolerance. It is easy to see how scab will affect the market value of stock. The Plant Disease Survey Bulletin reports losses from scab in the various States to run from 2 per cent to as high as 25 per cent. It has been reported that, in fourteen of the most important potato-growing States, approximately 6,000,000 bushels of the 1919 crop were rendered worthless by this disease.

### Symptoms

Scab, as it appears on young tubers, is a small, gradually enlarging, reddish or brownish raised spot. There may be but one such spot or there may be many of them. On older tubers, the spot is at first small and brown but usually enlarges to the size of a dime in area, and these spots may be so numerous as to cover the entire surface of the tuber. When young tubers become so extensively affected, the surface may become cracked in places as growth of the tuber continues.

Scab spots, as ordinarily observed at harvest, are brownish roughened areas, more or less circular and with irregular margins (figure 25). They may be raised somewhat above the surface of the healthy skin or may be more or less sunken. The term "warty scab" has sometimes been applied to the elevated type, while the type slightly or not at all sunken is called

"shallow" or "surface scab." When infection takes place early, the disease extends deep into the flesh forming a pit and this type is spoken of as "deep scab."



FIGURE 25. COMMON SCAB

Ordinarily only the skin and a few layers of cells below are affected although, in deep scab, the diseased area may extend a quarter or a half inch into the tuber. The scab organism does not produce a rotting of the flesh; nevertheless, rot-producing organisms may gain entrance through the scab lesion. White grubs, wireworms, centipedes, or mites sometimes live on the scabby tissue and thus enlarge and deepen the original injury.

Scab may be confused with other blemishes on the tuber, such as cracking and russetting, caused by chemicals applied to the soil or by an extensive growth of *Rhizoctonia* over the surface of the tuber, injuries from insects, quack-grass injuries, and enlarged lenticels.

### Cause

Common scab is caused by one or more species of *Actinomyces*, a group of organisms not yet well known, which lies at the border between true fungi and bacteria. There are many species of *Actinomyces*, some of which live in the air, some in water, and some in the soil. One authority reports that about twenty species are parasitic on plants and about as many on animal tissues. Several species cause warts and spots on the skin of animals and of man. The same authority found ten species (not including the one common in America) in scab spots on potatoes but was able to

produce scab by inoculation with only three of them. The name most commonly used in America for the species causing scab is *Actinomyces scabies*. It may be seen on the scab spots of freshly dug tubers as a filamentous whitish or grayish film that soon disappears when exposed to dry air. Examination with a microscope shows it to be a fine, filamentous, branching, segmented organism bearing spiral chains of spores. What appear to be resting spores may also be formed.

The scab organism is known to live from one season to the next in the scab spots of potato tubers and to be introduced into the soil when such tubers are planted. When scabby tubers are fed to animals, the scab organisms are able to pass through the alimentary tract of some animals and are thus introduced into the soil with the manure. They are able to live indefinitely upon organic matter, so that a rotation of crops will have little effect in ridding the soil of their presence. This fact helps to account for scab appearing on potatoes grown for the first time in a field or grown only after a long rotation with other crops.

While the organism is able to live from year to year in the soil and develop there under conditions favorable for it, nevertheless, it will attack potato tubers growing in its immediate vicinity. It enters through the lenticels or through cracks in the skin and sets up an irritation in the cambium cells beneath, which causes them to enlarge and divide abnormally. As these cells are invaded a new cambium is produced in the healthy tissue below. As this in turn becomes infected, regeneration of the cambium again takes place below the diseased area and this continued action carries the scab deeper and deeper into the tissue. In a very old scab spot, the diseased tissue may be more than one-eighth of an inch in depth. Whether the enlarged corky type, the shallow scab, and the deep scab are different stages in the development of a scab spot or whether they represent symptoms caused by different organisms is not definitely known. The scab organism may be found in this scabby tissue, but for the most part it is a surface organism and deep scab is only a relative term. Scab rarely extends more than one-fourth of an inch deep. No decay is ever caused by the scab organism, yet decay may follow scab by the entrance of saprophytic organisms through the lesion.

Experiments indicate that this organism develops scab on tubers most readily at high soil temperatures, such as occur during a period of hot summer weather, and that cool soil temperatures are unfavorable for it. This is confirmed by observations that scab is most abundant during hot summers and is less troublesome during cool summers. It also explains the statement made that early varieties suffer more from scab than do late varieties. It has been believed that scab develops best in moist soil, but more recent and carefully controlled experiments have shown that most

scab develops in the drier soils and is inhibited by the presence of much moisture.

Long continued experiments with sulfur applied to the soil as a means of control has led to the discovery that an acid soil is unfavorable for the development of the scab organism which thrives in an alkaline condition. Soil conditions are expressed commonly as hydrogen-ion concentrations, or pH values, and the concentration at which the development of scab is inhibited has been found to be about pH 5 or 5.2. The addition of materials to the soil, as lime, nitrate of soda, manure, and wood ashes, which increase the alkaline concentration (pH value) will naturally promote the development of the scab organism; while the application of acid-producing substances which decrease the pH value inhibits its development

### Control

As it has been demonstrated that the scab organism can be carried from one season to another in the scab spots on seed tubers, it is evident that seed treatment is one of the most important means of control (page 6). While disinfection is effective in destroying the organism on the surface of the seed tuber, the treatment has not been uniformly successful in reducing materially the scabbiness of the succeeding crop. Such results have been explained by the knowledge that the organism can live from year to year in the soil. If the soil is infested with the scab organism, the use of clean or disinfected seed will be of comparatively little value in preventing the disease from appearing on the new tubers. The recommendation that a sufficiently long rotation be followed to starve out the scab organism has two valid objections: first, it is not known but that the organism is able to live in the soil indefinitely; and secondly, many farmers in certain sections wish to grow potatoes successively on the same field for several or many years.

Since an acid condition of the soil is unfavorable for the development of scab, it seems reasonable to suppose that scab can be controlled by bringing about an acid condition of those soils and to avoid the application of substances that will tend to make the soil alkaline. For this reason such alkaline substances as lime, wood ashes, horse manure, and even nitrate of soda should not be applied to potato soils unless they are used with other substances that will counteract their alkaline tendency. A rotation of crops during which a sod or cover crop is turned under, the use of ammonium sulfate as a source of nitrogen in the fertilizer, or the application of sulfur to the soil, tend to bring about an acid condition so that the disease will be reduced materially or prevented entirely.

acid / If one brings about an alkaline condition of the soil by the continued use of ammonium sulfate or sulfur, it will be impossible to grow alkaline-

loving plants, as cauliflower, cabbage, alfalfa, and many others, until the soil condition is corrected by the use of lime or other alkaline-producing substances. As it is expensive to apply sulfur one year and lime the next to bring about changes in the soil reaction, it probably is wise to reserve a certain field for potatoes year after year. Potatoes, while they will tolerate an acid condition sufficient to control scab, will, nevertheless, be affected adversely if the soil acidity is much increased, as will happen if either ammonium sulfate or sulfur is applied year after year. Even a single application has a residual effect, so that care should be exercised, especially when sulfur is used, to make the single application only sufficiently heavy to bring about the desired result. Just how much to use depends upon the hydrogen-ion concentration of the soil before the application is made. The amount and the severity of scab present on the previous potato crop is some indication of this concentration. There is no danger that an injuriously acid condition will occur from the use of cover crops.

Either ordinary sulfur or inoculated sulfur may be used to control scab, but experiments seem to indicate that the latter is the more desirable. If ordinary sulfur is used, it should be finely ground, such as is employed in dusting fruit trees. The inoculated sulfur is finely ground sulfur to which a culture of a sulfofying bacterium has been added to bring about a more rapid oxidation of the sulfur after it has been applied to the soil than would occur without such a culture. Oxidation is necessary before the soil reaction is changed by the sulfur. Sulfofying organisms occur naturally in many soils but perhaps not in sufficient numbers to bring about as rapid an oxidation as when a culture is applied directly to the sulfur.

To be most effective the sulfur should be applied broadcast or drilled in with a grain drill or lime sower after the ground is plowed but before the potatoes are planted. When applied in the row with the fertilizer at the time of planting, injury is likely to result both to the vines and to the tubers. Tubers have become so badly russeted or cracked when sulfur has been applied in the drill row that they were as unmarketable as though badly scabbed.

The amount of sulfur to apply can be determined to some extent by the severity of scab in former crops. If the previous crop was severely scabbed, as much as 600 pounds an acre may be used; while a moderate or slight amount of scab indicates that a light application of from 200 to 300 pounds will be sufficient. If ammonium sulfate is to be used in the fertilizer, the amount of sulfur should be reduced by one-third to one-half, and be omitted altogether where scab is only slightly troublesome. Since the application of sulfur to parts of the farm where scab does not occur on the tubers is not only unnecessary but undesirable, growers should

fix thoroughly in mind the location of the areas in their fields where scab-affected tubers grew in order that the application of sulfur may be restricted to where it is needed. This may be done by staking the border of such areas at digging time and then mapping the field to record their location.

Sulfur has not been effective in controlling scab under all conditions, particularly in the heavier soil types and in muck soils; it has been more effective on the lighter types of soils. The reason for these results is not understood. Even in the lighter soil types, the control has not been perfect but usually good enough to give a profitable crop where the scab would have made potato growing unprofitable without a treatment.

In soils that are very alkaline it is not possible to apply sufficient ammonium sulfate to prevent scab without, at the same time, increasing the available nitrogen content of the soil to an undesirable degree. Then, too, the physical properties of this substance are such as to make it impracticable to use alone as a source of ammonia and yet have a fertilizer that will be in good mechanical condition. However, in fields producing potatoes that are but moderately or slightly scabby, the use of this material in the fertilizer as a large part of the nitrogen source will aid materially in obtaining a clean crop. In fields of badly scabbed tubers, the situation may be met by the application of some sulfur in advance of planting and also by the use of ammonium sulfate in the fertilizer. The continued use of ammonium sulfate as the only source of nitrogen will result in decreased yields through the increased acidity of the soil produced by it. Nitrate of soda, on the other hand, tends to produce an alkaline reaction in the soil and its continued use will result in increased scabbiness of the crop. When a field already produces very scabby potatoes, nitrate of soda should form only a small part of the source of nitrogen, the greater part being supplied by sulfate of ammonia and some organic material.

### POWDERY SCAB

(Caused by *Spongospora subterranea*)

Powdery scab affects the common potato and at least five other species of the genus *Solanum* besides the tomato. Apparently it has not caused any material damage to plants other than the potato. Very little is known of the relative resistance of potato varieties to the disease; however, all of those tested in this respect show some degree of susceptibility.

The terms, *corky scab*, *spongy scab*, *Spongospora scab*, *potato canker*, and *powdery scab* have been applied to this disease but the last term is the one most commonly used in English-speaking countries.

This disease has undoubtedly existed on the native varieties for many years in Ecuador and Peru, the home of the potato, and is probably

indigenous there. It was described first in 1841 from affected potatoes in Germany. Afterwards it was found in England, Wales, Scotland, and Ireland. The first record of its appearance in North America was in 1913 when it was discovered on potatoes in Quebec. The same year it was found in Maine and in two other States. It is now known to occur in a number of the northern States and adjoining provinces of Canada, and has been reported from Florida and from South Africa.

Although it has been reported as causing considerable loss in European countries, it has never been of great importance in this country. It occurred to some extent in a few fields of Maine and New York during 1913-14 and a quarantine was placed on those sections. Later experiments showed that it would not become serious in the warmer sections of the country and the quarantine was removed in 1915. Since that time it has scarcely ever been observed in the United States, even in those localities in which it was first found. The principal damage from the disease on the potato is the rot about the scab pustules that sometimes occurs after the tubers are placed in storage.

### Symptoms

The disease on young tubers first appears as small discolored pimples, or pustules, that are in patches or scattered over the surface. As these pustules enlarge, they break through the surface which splits in a stellate manner and curls back exposing a brown powdery mass of spores within (figure 26). These spores are disseminated readily after the pustule is ruptured and leave a shallow crater-like pit less than an eighth of an inch in diameter and with a circular margin. This is the appearance usually observed on harvested potatoes, for the pustules break open easily after becoming dry. In storage, a dry sunken rot may develop about the pits. A cankerous stage of the disease has been described as appearing in low wet lands, in which case the deeper tissues of the tuber become infected and are often invaded by rot-producing organisms which completes the destruction.

The disease may affect the roots as well as the tubers.

### Cause

Powdery scab is caused by a slime-mold parasite named *Spongospora subterranea*. The brown powdery mass within the pustules on the surface of the tubers consist of many spore balls each of which is made up of several spores loosely arranged. These spore balls become distributed in the soil or are introduced into new areas by means of affected tubers or with healthy tubers that have become contaminated by carrying the spore

balls on their surface. These spores are not destroyed by passing through the alimentary tract of the pig and probably other animals and may thus be scattered with manure.

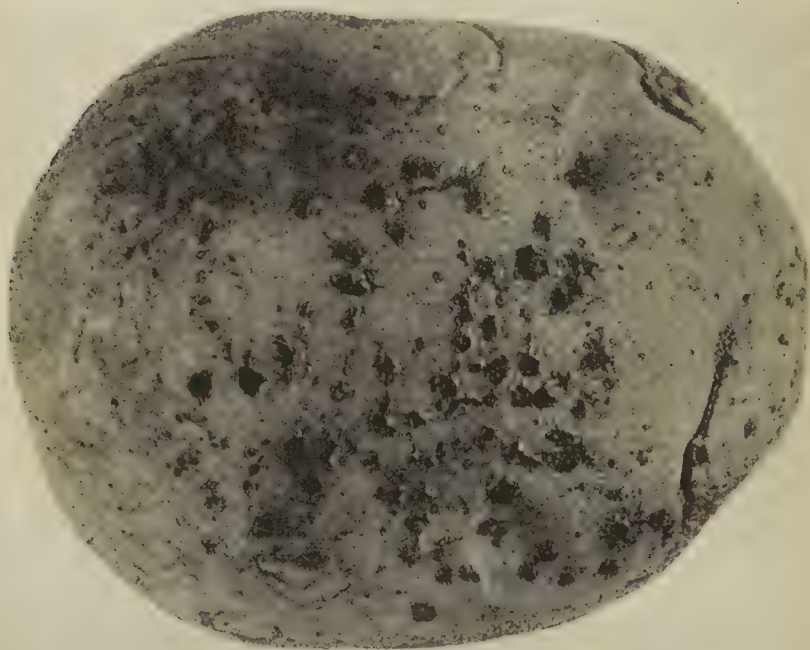


FIGURE 26. POWDERY SCAB

The spore germinates by releasing a tiny naked protoplasmic body like an amoeba which feeds upon available material and enlarges to form a plasmodium, or several amoebae unite to form such a body. The plasmodium enters the tuber or root through the epidermis by pushing apart the cells sufficiently to enter. After it is beneath the epidermis, the plasmodium spreads out in all directions into a flat disk-shaped body and sends strands of protoplasm, or pseudopodia, down between the cell wall which become softened and altered so that the organism is able to penetrate them, to feed on their contents, and to destroy them. The organism does not proceed to a depth of more than a few cells at this time but by division a number of plasmodia are formed which are used in the production of a new spore mass beneath the cuticle.

After spore production has taken place, new plasmodia may be formed which continue to advance into the tissue to a depth of about half an inch

and produce the dry rot about the old pustule. Under very moist soil conditions these rotted spots may develop into the deep cankers that have been mentioned as occurring in European fields.

The slime mold may live for at least five years in the soil and probably longer. It even is possible that it may live indefinitely as a saprophyte or the plasmodium may become encysted and exist in that form for a long time.

Cool weather and low wet soil is most favorable for the development of the organism. Lime seems to increase the amount of disease as it does in the case of common scab. While powdery scab is widespread, it occurs in the various countries only in limited areas where conditions are favorable for its development.

### Control

Disinfection of the seed tubers with either the standard formaldehyde or corrosive-sublimate solutions for one and one-half hours or with hot formaldehyde for five minutes is said to be fairly effective when clean soil is used. Application of sulfur to infested soil has reduced the scab considerably. Clean land should be used where possible and unaffected seed used in planting. As a matter of fact, the disease is of so little importance in most potato districts of the State that it need be given no consideration.

### SKIN SPOT

A blemish of potato tubers known as *skin spot* has been described and reported from England, Ireland, Germany, Canada, and the United States, and has been observed on potatoes from Denmark consigned to our country.

The spots appear as small, round or oval, closed pustules, or pimples, raised at the middle but depressed at the margin, dark or bluish brown outside and olive brown to brown inside. The spots may be no larger than an eighth of an inch in diameter but vary in size and may coalesce. The flesh of the tuber beneath the spot is brown and dead, yet this does not extend so far but that it is removed by the ordinary depth of paring.

A number of organisms have been reported as causing skin spot including *Spicaria*, *Phoma*, *Rhizoctonia*, and *Oospora pustulans*. One American investigator, after a careful study, concludes that it is caused by *Spongospora subterranea*, the parasite producing powdery scab, and that the raised pimples are the immature pustules of this organism. He thinks that the organisms found by other investigators are merely secondary invaders gaining entrance to the powdery-scab lesion during the period of storage. Some English investigators, however, have proved to their satisfaction that skin spot in England is produced by *Oospora pustulans*.

## SILVER SCURF

(Caused by *Spondylocadium atrovirens*)

Silver scurf is a disease of the tubers. It is not known to affect any other plant or any other part of the potato. No careful studies have been made to determine whether there is any difference in varietal susceptibility to this disease.

The term "silver scurf" was applied because of the silvery appearance of the spots when the tuber is immersed in water.

Silver scurf was discovered first in Austria in 1871 and is now known to exist in other European countries. It was not observed in this country until about 1913 but since then it has been found in many of our potato-producing States.

Although it mars the appearance of the tuber, the disease is not of great economic importance since it does not affect the food value materially. The principal loss is shrinkage in storage which is caused by a loss of water through the diseased skin.

### Symptoms

The disease affects only the skin, over the surface of which it appears as brown or dark-olive blotches of various sizes, sometimes involving half or more of the surface. These areas usually take on a silvery or glistening appearance, especially when the tuber is wet. This is due to the outer cells of the skin being pushed up by the mycelium of the casual fungus. The olive color is caused by the fruiting bodies of the parasite which develop when the affected tubers are left in a moist place. Potatoes stored for a long time under warm moist conditions become dull black and look as though they had been dusted with soot. Late in the storage season the affected tubers may shrink to such an extent that distinct folds or ridges appear on the surface. Red-skinned potatoes lose their color when this stage has been reached. Numerous, small, compact, black bodies, called sclerotia, are commonly observed on affected surfaces, even at harvest; but their relationship to this disease has been questioned.

### Cause

Silver scurf is caused by the pathogene *Spondylocadium atrovirens*. This fungus, under moist and favorable temperature conditions, produces over the surface of the affected area a large number of fruiting bodies consisting of minute stubby stalks bearing a number of brown several-celled spores. It is possible that these spores, when mature before harvest, may live over winter in the soil, but they are borne also while the tubers are in storage and may germinate and infect other tubers with which they

come in contact. The fungus enters through the lenticels or directly through the surface layer of cells and develops in the corky layer of the skin. The outer affected layers may slough off so that the water within the tuber escapes readily through the skin. Infection of new tubers takes place from the development of the fungus on the seed piece or possibly from the spores or pieces of mycelium that have remained in the soil. The fungus apparently develops under conditions most favorable for the development of the potato but it is reported that it is favored by the wetter parts of a field.

### Control

Treatment of the seed with formaldehyde or corrosive sublimate has not been effective altogether in destroying this fungus. Probably the only way to avoid the disease is by the use of healthy seed and a rotation of crops.

### WART

(Caused by *Synchytrium endobioticum*)

Potato wart affects potatoes and tomatoes and has been produced artificially on black nightshade and bittersweet. The damage caused by the disease is greatest on the potatoes because it injures the salable parts; the tomato shows considerable resistance to the disease.

Out of 103 American varieties of potatoes tested, 34 are immune. The potato types showing immunity are Green Mountain, Irish Cobbler, Spaulding Rose, McCormack, Burbank, and Ehnola; while those susceptible are Rural New Yorker including other Rural varieties, Early Ohio, Early Rose, Bliss Triumph, Early Michigan, Pearl, and Up-to-date. Tests conducted in England have demonstrated the immunity of several European varieties.

Like other diseases, a number of names have been applied to this one. The name most commonly used in this country is potato wart; it has also been called black wart and potato canker. In Europe it has been called black scab, warty disease, canker, tumor, cauliflower disease, and other names.

The disease was discovered in Hungary in 1896 and about the same time in England, where it probably had existed for many years. Since then it has spread to other parts of Europe and to North America. The presence of wart was reported in 1906 in New Foundland and has been found in the adjacent islands of St. Pierre and Miquelon. In 1918 it was discovered in gardens in many of the mining villages of Luzerne, Schuylkill, and Carbon Counties of Pennsylvania. The United States Department of Agriculture then conducted an extensive survey in order to determine how

widely the disease had been introduced. As a result of this survey, the disease was discovered in other mining districts of Pennsylvania, West Virginia, and Maryland. No trace of it was found in New York or other States. In 1912 a federal embargo had been placed on potatoes from European countries known to be infested, but before this was done several million bushels of the crop of 1911 and of previous years were imported from England, Ireland, and other European countries. Large quantities of these were distributed in the mining districts of Pennsylvania, and it seems likely that the wart was introduced with such shipments. A strict quarantine was placed on the infested districts in this country and apparently there has been little or no spread since that time.

Very few marketable tubers are produced when this crop is grown year after year on the same infested ground and when conditions are at all favorable for the development of the disease. There is a considerable economic loss in a number of European countries as a result of the disease; but in this country there is very little loss, for the disease is restricted to a comparatively few localities in mining districts where potatoes are grown only for home consumption. Even in these places only resistant varieties are permitted to be grown, so that the principal loss must be charged to the maintenance of the quarantine and to the investigations that are being conducted.

### Symptoms

It is said by some that the disease appears on all parts of the plant but ordinarily it is confined to the lower part of the stems and to the tubers and stolons. Apparently it does not often occur on the roots.

On the tubers the disease shows as prominent outgrowths or warts which originate in the eyes and vary from the size of a pea to that of the tuber itself (figure 27). At first the warts have the normal color of the tuber but they become brown with age and at harvest may be black or nearly so. The warts resemble somewhat in shape crown galls on fruit trees and other plants, and consist of a number of branching lobes closely pressed together. A slightly affected tuber may have only one eye transformed into a small wart, while those more severely diseased may have such numerous large warts that the entire tuber appears as a warty mass. These warts may decay before harvest or during storage, the decay sometimes involving the tuber itself. The warty masses at the base of the stem may extend above ground, in which case they may become green in color like an exposed tuber. Usually it is impossible to detect affected plants without digging them, for the growth of the vine is normal unless, as is claimed by some, it remains green longer than do healthy plants.

### Cause

The wart disease is produced by one of the lower fungi named *Synchytrium endobioticum*. The fungus body is not mold-like as is the case with many fungi and is so small that it scarcely can be seen with the naked



COURTESY OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

FIGURE 27. THE WART DISEASE ON TUBERS

eye. The fruiting bodies of the fungus are minute yellow-colored, globular, thick-walled bodies known as sporangia. These are very numerous just beneath the surface of the wart and are released into the soil by the decay of the malformed tissue. The sporangia supposedly are able to live for years in the soil, but, when favorable conditions arise, they germinate by the release of a whole litter of very small oval-shaped free-swimming spores. These spores move about in the soil moisture, and, if potatoes are near-by, some spores find their way to the eyes or other tender parts which they are able to penetrate. Once within the tissue, they continue to develop by living on the cell contents. After a period of development

within the host plant, which they never penetrate deeply, new sporangia are formed and the life cycle of the organism is complete.

The actual injury done by the parasite is not due to the destruction of the invaded tissue but to an irritation which brings about an extensive multiplication of the host cells.

The disease is spread by means of the contaminated soil or affected tubers. Local spread doubtless takes place in both ways. The spread from one country or one continent to another has taken place entirely through the shipment of affected seed.

### Control

The first means of control to be considered by any grower is that of exclusion. Because of quarantines no seed should be or is likely to be imported from regions where the disease is known to exist. When once the disease organism has become established there is no known means of control except through the use of immune varieties. Fortunately, there are now known a number of such varieties that are of commercial value and have been in general use for a long time. Experimental work in breeding will doubtless yield Rural and other types resistant or immune to the disease.

### STORAGE DRY ROT

(Caused by *Fusarium* sp.)

Under the term *storage dry rots* is here discussed such dry rots as commonly occur in storage cellars and houses in New York State. There probably are several related organisms involved, one or more of which may cause rots of fleshy parts of some other plants when placed in storage.

Storage rots have different names, depending upon the nature of the rot and of the organism causing it. In one form or another they occur wherever potatoes are stored and have probably existed as long as the practice of storing has been in use.

The losses occasioned by storage rots are often very large. As high as from 40 to 60 per cent of the stock in the spring has been reported as decayed. Not only are there heavy losses in individual cases but the disease is so general that the total reduction in bushels must be very large. There must be included here the losses that result from the use of partly decayed seed that is sometimes planted and which may fail to grow or may give rise to a weak hill.

### Symptoms

Each of the various tuber rots have their own peculiar symptoms. Some of these rots are described under the headings late-blight rot, black leg, potato wilts, and black-heart. One of the more common dry rots in this

State appears on the tuber, soon after the beginning of storage, as a sunken discolored area usually starting in a wound or bruise. This spreads slowly until half or more of the tuber is involved. It extends deeply into the flesh and causes it to become discolored, dry, and cheesy, or friable, in consistency (figure 28). As the rot progresses, the skin becomes sunken and



FIGURE 28. STORAGE DRY ROT OF THE TUBER

wrinkled. Tufts of pinkish or whitish fungous bodies break through the dead epidermis and appear upon the surface. The fungous growth may also be found in the interior of the rotted area.

A dry, powdery, storage rot is very common in the potato sections of the West, and a so-called "jelly end-rot" occurs in the West and in the Central States. A soft bacterial rot may accompany any of these rots if the storage place is warm and moist. Such a wet rot is often observed in wet soils following late blight.

The storage dry rot is favored by moderate storage temperatures and develops but slowly, if at all, when the temperature is kept at 40° F. or below. A moist condition on the surface of the tuber appears to favor

infection but is not necessary after the rot is started as sufficient moisture exists in the flesh of the tuber to favor its development.

### Cause

Storage dry rots are caused by one or more species of *Fusarium*. Each species produces a more or less typical rot but sometimes more than one may be present in a lesion. These *Fusaria* are soil organisms and doubtless commonly gain entrance to the tuber at harvest through wounds caused in digging. Spores are present in the soil and come in contact with wounds within which they develop, or they become lodged on the surface of the tuber and enter the tuber when it is bruised in subsequent handling. Once the fungus has gained entrance to the potato, it develops within and around the cells, living upon their contents and causing the dry decay. After a period of growth, tufts of fungous threads are pushed up through the skin of the tuber and on these are borne numerous spores. These may be disseminated in the storage house where they lodge on the surface of other tubers and on the walls and floors. Here they may remain until a new crop of tubers is stored and then cause infection. The spores may also be introduced into the soil with affected tubers or with those contaminated with the spores lodged on their surface.

Sometimes the wounds in tubers will heal over by forming a callus before infection has proceeded far into the flesh. This healing is possible when the tubers are stored in a dry cool storage unfavorable for the development of the fungus.

### Control

As the fungus enters the tuber largely through mechanical injuries, the control measures recommended are the handling of potatoes so that they will be wounded as little as possible and the cleaning and disinfecting of storage houses. Discarding all rotted tubers for planting and disinfecting the seed should largely prevent the introduction of the fungus into potato fields. These methods, of course, will not always give complete control but they should aid in reducing materially the loss resulting from this disease.

### BLACK-HEART

(Caused by lack of oxygen and high temperatures)

Black-heart is a disease of harvested potato tubers in which the central area becomes dark colored. Any variety of potato may become affected at any time after harvest, provided that conditions for its production are favorable.

### Symptoms

The tissues of the tuber injured by black-heart are those which occupy the central area called the medullary region. The darkened area may be irregular in outline and is almost always elongated in the direction of the long axis of the tuber (figure 29). Lobes or branches of the main



FIGURE 29. BLACK-HEART OF POTATOES

affected area may extend toward the eyes. The color of this area varies from gray black to coal black and the tissue is usually rather firm at first.

Occasionally large black spots are scattered irregularly through the flesh of the tuber instead of in one central area and this is sometimes associated with a discoloration of the vascular tissue.

When a tuber affected with black-heart is exposed to dry air for a few days, a cavity develops at the center, sometimes of considerable size, which is lined with a tough, black, rubber-like tissue. This cavity very probably results from the shrinkage of the discolored tissue due to the evaporation of the water from the surface.

Even severely affected tubers may develop normal sprouts and a normal growth of vines. However, tubers may be subjected so long to the conditions under which black-heart is produced that the eyes or sprouts are destroyed.

### Cause

Black-heart is due directly to a lack of sufficient oxygen to support respiration. The cells of dormant tubers contain living protoplasm and require oxygen for respiration just the same as do hibernating animals. Respiration of tubers takes place very slowly at low temperatures and increases as the temperature rises. It has been found that more than ten times as much carbon dioxide is respired by potato tubers at a temperature of 113° F. than is respired at 50° F.

Even at low temperatures black-heart will result when tubers are stored for any length of time in the absence of air. They may be stored in ordinary cellars or other storage places for a period of five or six months without special attention to ventilation if the temperature does not rise much above 40° F. and provided they are not piled more than 6 feet deep. But when the temperature rises above 50° F. for a few days, black-heart may result. It is, therefore, during the warm weather of spring while the potatoes are still in storage that the trouble is most likely to originate. It may occur even in potatoes stored in pits if they are piled deeply and if the spring temperature becomes very warm, unless provision for ventilation has been made. At temperatures of from 50° to 70° F., potatoes piled to a depth of 3 feet or more for a period of several weeks are likely to have black-heart; if kept at 100° F. for a few days, the disease will develop regardless of the ventilation provided. High temperatures with poor ventilation occasionally prevail in cars in which potatoes are shipped, either because of hot weather or because the artificial heating during cold weather is not properly regulated. Under such conditions the discoloration of the tissue takes place readily. For the same reason tubers left exposed to the sun for a considerable period during hot weather are likely to become affected with black-heart.

### Control

Control obviously consists in providing adequate ventilation of storage houses and in maintaining low temperatures where possible. The method of providing ventilation in storage is discussed under "Storage," page 32.

### FROST NECROSIS

Freezing constitutes the greatest hazard confronted by the northern potato grower and shipper, and often affects carrier, wholesaler, retailer, and consumer. The losses from freezing, extending from the last month of growth throughout the winter shipping season, to say nothing of the reduction in stands from planting frosted seed and of the freezing or frosting of early-planted potatoes, amounts to an enormous figure. The loss cannot be determined from the number of softened and collapsed tubers that are found after a freeze, for tubers may be severely damaged by freezing without showing any external evidence of such injury. When

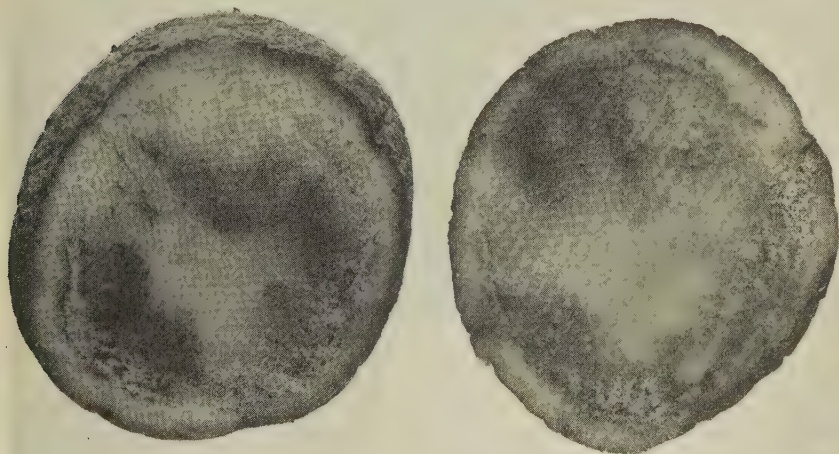


FIGURE 30. FREEZING CAUSES DISCOLORATION OF TUBERS

such tubers are cut, they show various types of discoloration and collapse that may be confused with internal lesions caused by disease organisms (figure 30). This has often led to mistaken conclusions as to the cause of the injuries.

All varieties of potatoes at any stage of their development and storage are subject to injury from low temperature, but investigation indicates that the freezing point of the tubers of certain early varieties, like Irish Cobbler, Triumph, Spaulding Rose 4, is at a slightly higher temperature than is that of smooth and russet Rurals and Green Mountain varieties. It has also been shown that it requires a slightly lower temperature to injure any variety in the earlier part of their period of storage than in the latter part. These differences, however, are very slight, scarcely ever being more than one degree Fahrenheit and often less, so that they are hardly worth considering. Individual specimens of any variety will freeze at a higher temperature than other specimens of the same variety, thus it is possible to find frozen individuals in a bin or a car that were all right when placed there. Usually, however, the presence of frozen individuals scattered among others in a bin or car indicates that the freezing took place before they were placed there, while the presence of a number of frozen tubers in one location indicates that freezing occurred after they were placed in that location.

When a tuber that has frozen solid is allowed to thaw out, it becomes moist on the surface, softens, and collapses. The interior becomes soft and watery. If such a frozen tuber is cut open shortly after it has thawed, it will at first show no discoloration but the cut surface will soon become pink, then red, brown, and finally inky black. This change in color appears to be due to the presence of an oxidizing enzyme that becomes active on injury to the cells. If left undisturbed, the potato will gradually shrivel and dry up as the water escapes to the surface and evaporates. Sometimes a tuber will soften only on one side or on one end because only that part was exposed to freezing temperatures. This softening and shriveling may appear after the tuber has been placed in storage or in shipment and may resemble tuber rots caused by disease organisms. Certain rot organisms may enter the frozen part and continue the destruction of the tuber.

When the falling temperature stops short of the time or the degree sufficient to bring about a uniform or complete freezing of the tuber, certain inner tissues, particularly the vascular tissues, become injured; however, there may be no external evidence of such injury until the tuber is cut open. These internal injuries appear as discolored areas which do not become well marked until four or five hours after the freezing has taken place.

The discolored cells that have been killed in this type of freezing are confined largely to the vascular elements and the cells adjoining them. The tissues at the stem end appear to be more susceptible to freezing than do those at the bud end, inasmuch as the injury will be found there if

anywhere on the tuber. There is considerable variation in the appearance of the injury, depending somewhat upon the temperature and the time of exposures. Consequently no two frosted tubers, even when exposed to the same temperature, will show exactly the same kind of lesions. These necrotic lesions have been roughly classified into three general types as follows:

*Net*, in which the fine divisions of the vascular elements extending into the cortex and inner pith region become blackened, and thus give the

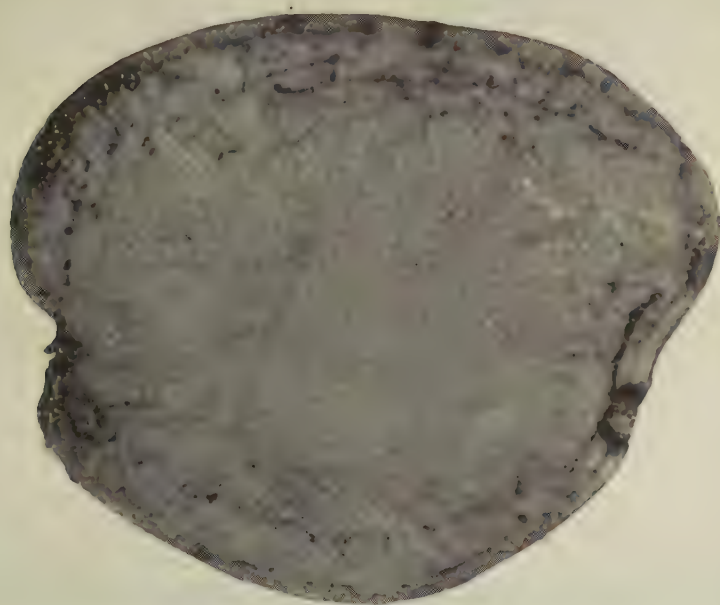


FIGURE 31. FREEZING CAUSES NET NECROSIS IN THE TUBER

cut surface a netted appearance (figure 31) which may be indistinguishable in itself from net necrosis brought about from other causes.

*Ring discoloration*, in which the vascular ring and the cells adjoining become blackened. This discolored ring may be continuous or it may be interrupted; it may be narrow throughout or it may be wide in places where freezing has extended into the flesh. It resembles closely the vascular discoloration produced by wilt-disease organisms.

*Blotch*, which involves large or small areas, ovoidal in shape or irregular in outline, usually located in the vascular ring or cortex but sometimes found in the pith. These areas vary in color from pearly gray to black.

Sweetening of the flesh has been ascribed to frosted tubers, but it has been shown to be brought about by continued exposure to low temperatures above the freezing point and not to freezing itself. This sweetness is due to the conversion, at such temperatures, of some of the starch to sugar.

### Cause

While it is obvious that the freezing of tubers is due to a low temperature, it was not until careful investigations were conducted that the actual freezing point of the potato tuber was determined, or was it known until then that these various necrotic lesions of the interior of the tuber may be produced by this cause. The freezing point has been determined to be from  $29.66^{\circ}$  to  $28.13^{\circ}$  F., depending on variety and period of storage, but potatoes may be undercooled several degrees below this without freezing taking place. If, while they are undercooled, the tubers are subjected to a mechanical disturbance, such as a jar, freezing will immediately take place. Injury results when ice crystals form in the spaces between the cells. The force of the jar necessary to bring this about depends upon the degree to which supercooling has gone. When the surface of the tuber is wet, as with water or with juice from a bruise, freezing will take place before supercooling has proceeded very far, but, if the surface is dry and the tuber is not disturbed, supercooling of some tubers may reach a temperature of  $23^{\circ}$  F. for several minutes before freezing takes place. When the outside temperature drops slowly, the degree of supercooling will be lower before freezing occurs than when the outside temperature drops rapidly. However, tubers may be exposed to a temperature of about  $26.5^{\circ}$  F. for a considerable period without freezing if they are not moist on the surface and not subject to mechanical disturbance.

It has been found that the sprouts are not so susceptible to freezing injury as is the tuber itself. When sprouted tubers were exposed to a sufficiently low temperature to produce necrosis in the tuber, the sprouts appeared uninjured. When such tubers are planted, the sprouts, although starting more slowly than those from uninjured tubers, nevertheless, develop into healthy vigorous vines and produce healthy tubers. However, when the tubers are injured extensively by the frost, they rot before the sprouts are fully developed and thus cause a poor stand.

### Control

It is obvious that control of frost necrosis consists in protecting the tubers from low temperatures. This involves the completion of the harvest before the season in which low temperatures are likely to occur, the storage of the tubers where the temperature can be maintained above

the freezing point, and sufficient protection from cold when the tubers are being transported. Those interested in the construction of proper storage houses or in a method of loading cars to prevent freezing may obtain this information from various bulletins that have been published on the subject.

Frosted stock should not be used for planting unless care is taken to discard all tubers showing internal lesions.

### NET NECROSIS

The name *net necrosis* has been given to a condition in which a network of brown or black streaks is present in the flesh of the tuber. These may be found in a part or all of the flesh and usually are found in the cortical tissue below the skin. No evidence of net necrosis can be detected on the surface of the tuber. Although edible, affected tubers lessen the value of a stock if many are present, and they are undesirable for seed because they often produce spindling sprouts.

This condition is not a disease but is a symptom of frost necrosis, of Fusarium wilt, of leaf roll, and probably of other conditions.

### SPRAIN

Sprain, a disease of the tuber, known also as internal disease, internal brown spot, brown fleck, and streak, occurs occasionally in Scotland, England, Ireland, Germany, the United States, and probably in other countries. Ordinarily it is not severe and the only reason for including an account of it here is because it resembles in a way, some symptoms of yellow dwarf, net necrosis, and wilt.

Sprain appears as few or numerous, brown or dark-colored, blotches or streaks in the flesh of the tuber. These discolored areas are of various sizes and shapes that may or may not be connected with each other. They may appear as small specks or they may be in more or less concentric circles. They are not confined to the stem end nor do they appear to spread from that end. Usually tubers affected with sprain show no indication of it on the surface nor are the vines abnormal in any way. Discolored spots on the surface of the tuber have been observed just above similar subepidermal spots. Very young tubers may be affected.

The cause of the trouble has not been determined nor is it certain that it is due to any one cause. The use of affected tubers for seed does not necessarily result in the occurrence of sprain in the new crop. The trouble appears more commonly in light or stony soils than in medium or heavy ones and is more prevalent in dry seasons. It is thought by some investigators that the trouble is brought about by the lack of water. An English investigator has recently concluded from his experiments that

this disease is due to a bacterium which he has named *Pseudomonas solaniolens*.

No definite control measures have been recommended.

### SECONDARY TUBER FORMATION

Occasionally tubers when planted give rise to a number of new potatoes on the surface of the old seed piece (figure 32) but no sprouts are formed or, if so, they extend from the new tubers. Sometimes these secondary tubers are grown on the old tuber while the stock is yet in the bin. A



FIGURE 32. SECONDARY TUBER FORMATION

peculiar condition has been reported in which a new tuber has been produced within an old one.

The formation of secondary tubers does not take place until after the rest period has been completed and usually takes place late in the spring or in the summer. It is said to be more pronounced on early potatoes. It sometimes occurs so generally in a given stock as to cause considerable loss, since the secondary tubers are not marketable.

Investigations indicate that secondary tuber formation can result from two sources. One source is associated with virus diseases but this does not occur commonly. The other is associated with storage conditions. Storage that favors early sprouting predisposes the potato to form secondary tubers, particularly if the sprouts have been removed one or more times before the seed is planted in a cool dry soil. Even under more favorable soil conditions such potatoes will begin the formation of normal new tubers earlier than potatoes that have been stored at cooler temperatures. Potatoes having had sprouts removed four or five times before

planting may produce secondary tubers even when the soil in which they are planted is warm and moist.

The conclusion is drawn from some investigations that the tendency of secondary tuber formation is increased by the greater concentration of the cell sap due to loss of water from the tuber through the sprouts.

In order to prevent the formation of secondary tubers it only is necessary to keep the storage cool and thus prevent sprouting. If the storage is located so that it is impossible to prevent this early sprouting, secondary tuber formation can be prevented by keeping the seed tubers in the light so that only short stubby sprouts will be produced. Planting the tubers at a time when the soil is warm and moist will overcome this tendency to some extent.

### SPINDLING SPROUT

The term spindling sprout is used to designate a condition in which slender weak sprouts are produced instead of large vigorous ones. This condition has frequently been observed not only in this country but in France and Germany. The loss resulting from spindling sprout is probably not large on the average. Yet reports have been received which show that more than 30 per cent of tubers of some lots were thus affected and



FIGURE 33. SPINDLING SPROUTS COMPARED WITH HEALTHY SPROUTS  
The healthy sprout is on the right

that fields planted with such stock were plowed up because of poor stands and weak plants. It appears to be more general some years than others.

### Symptoms

The name is most applicable because the sprouts are usually very slender, even thread-like. These sprouts come from all or nearly all the eyes of the tuber, whereas in healthy tubers the sprouts, unless they have been removed several times previously or hindered in their growth, will come only from the bud end of the tuber. There are all variations in spindliness from sprouts that are needle-like to those nearly normal to size. Occasionally tubers may be found with both very slender sprouts and with nearly normal ones (figure 33). Small tubers may be formed at the base of spindling sprouts. Usually there are no lesions either on the surface or within the tissue that would enable one to detect the weakened tubers.

If tubers with spindling sprouts are planted, they may produce no plants at all because of the inability of the weak sprouts to push their way up through the soil or they may give rise to a number of slender weak stalks that are capable of yielding but few, if any, marketable potatoes.

### Cause

Spindling sprout may be caused by unusually hot dry weather during the period when the tubers are forming. Apparently the temperature is the factor of greater importance although the exact nature of the injury is not known. It has also been shown that weak spindling sprouts may result from repeated removal of sprouts, as is sometimes practiced when the seed starts sprouting considerably in advance of planting. Experiments have shown that weak sprouts may be caused by long periods of cold storage after the rest period of the tuber is over.

It has been observed that tubers from leaf-roll plants may have weak sprouts, some being very spindling. Such spindling sprouts on tubers affected with leaf roll show a net necrosis of the flesh. It has also been observed that tubers showing a net necrosis that has resulted from the *Fusarium*-wilt disease may produce spindling sprouts. It thus appears that spindling sprout is the name of a symptom that may result from any one of several causes rather than being a particular disease.

### Control

If the tubers are sorted after sprouting begins, it is an easy matter to separate and discard for planting all tubers showing weak or spindling sprouts. Such tubers if not affected with net necrosis may be used as table stock, and, if net necrosis is present, they may be fed to animals.

### SUNBURN

When the tubers are exposed to sunlight, especially immature tubers that have not yet developed a corky skin, they turn green. This green color is due to the development of chlorophyll in the cells beneath the skin just as it develops in leaves. When potatoes are not hilled, or, if the ridges have been washed away by rain, the part of the growing tuber exposed to the sunlight becomes greened. This green color is objectionable because the tissue has a bitter flavor and is poisonous to some people. It does not impair the use of the tuber for seed purposes.

### SUN-SCALD

Long or frequent exposure of tubers to hot sun results in the death of the exposed tissue which becomes watery and turns brown. Sometimes these affected areas dry to a hard leathery consistency or may become chalky. More frequently, however, rot organisms gain entrance and complete the destruction of the tuber.

Cases have been known where tubers have been exposed to the hot sun to dry after the seed treatment and have thus become badly scalded. Black-heart often accompanies sun-scald and may take place in exposed tubers when the temperature is not high enough to cause scald.

### LIGHTNING INJURY

Occasionally a potato grower walks through his field to see how the crop is growing, or possibly he is cultivating, when suddenly he comes to an area where nearly all the plants are dead or dying. Such an area may be circular in shape (figure 34) and include one to three square rods or extend up and down a few adjacent rows. At once the grower becomes excited if he has not observed a similar trouble before, and draws the conclusion that some new disease is going to take his entire crop. He seems justified in this opinion, for the plants ordinarily are completely dead in the center of the spot; while surrounding this is a zone where the plants are in various progressive stages of collapse, the worst affected ones always being farthest from the outer margin.

Someone who knows the cause of the dead plants, reminds the grower of a thunder shower that occurred a short time before and then all is made clear; that is, if not too long a time has intervened between the observation and the date of the injury. If the trouble has taken place recently, the weeds are killed as well as the potatoes. Some of the potato vines along the outer boundary, will have their entire stem shriveled and brown while the leaves remain green. In lesser injury the browning will not include the entire stem, but extend as a streak from the ground upward, sometimes reaching the tip of the plant.



FIGURE 34. POTATO PLANTS KILLED BY LIGHTNING

Note the circular area in the field where the plants were killed by lightning

Many people can hardly believe that the trouble is due to lightning, for there is often a mistaken notion that an electric bolt will tear a hole in the ground. A disturbance of the soil, however, does not take place. There are other reasons why a grower may be confused in his diagnosis if the injury is not of recent origin. The weeds grow again quickly, and then he wonders why they were not killed. Secondly, on examination of the stems he is almost sure to find fruiting bodies of some fungi, which may appear as the primary cause, even though they entered after the tissue was killed.

There is only one disease that might be mistaken for lightning injury. The fungus known as *Fusarium cumartii* may start with one hill and gradually spread in each direction until a circular area is invaded and some of the plants may be killed. Usually there is a wilting first and a yellowing of the foliage. In advanced cases the tubers may begin to rot from the stem end. Lightning does not cause such a stem-end decay. Furthermore, the *Fusarium* trouble continues to spread while that caused by lightning remains within the bounds covered by the electric bolt. Taking all these things into consideration it is fairly easy in the field to determine when lightning has caused the injury.

#### POTASH HUNGER

During the World War when Germany was shipping no potash to this country, a peculiar injury occurred on potatoes in many fields, especially along the eastern coast. In very mild cases the only difference was a

darker green color in the foliage than ordinarily is present. In more advanced stages, however, the upper surface of the leaf assumed a characteristic bronze color. The tissue between the veins bulged upward, while the margins of the leaves curled downward. After the bronzing of the foliage, it turned brown and died prematurely. In many cases the dead spots on the leaves were similar to those of hopper burn or early blight. Even the stems were affected, and either died or became so sickly that such weak parasites as *Phoma* could enter to complete the destruction.

Since the war there has been only an occasional report of such injury to potatoes. It has been found that the abnormal condition can be corrected by the use of a balanced commercial fertilizer which contains potash or by a generous application of barnyard manure.

### GIANT HILLS

After the first early frosts, some individual potato vines remain green while all the neighboring ones have been killed. If these frost-resisting plants are examined during the growing period, they show a much coarser stalk than does the normal plant. Often there is only one stalk to the hill, the leaves at the top are small and the edges of the leaflets are rolled upward. When the tubers of such a hill are dug, they usually are found to be coarse and irregular in shape, few in number, and may be rather knobby. The size of the vine and tubers has earned the name "giant hill."

The plants grown from such tubers will produce similar plants under New York condition. There is a belief that the giant hills are an indication that infection with degeneration diseases has taken place, and that under a favorable environment for the disease, leaf roll, spindle tuber, or similar troubles may result. Such a belief has not found support in this State, for many fields with leaf roll may show no giant hills, and seed stock that has these abnormal vines year after year remains almost free from leaf roll and from spindle tuber.

### ENLARGED LENTICELS

When a potato with numerous white specks is shown to a group of potato growers, some one of them invariably will remark that these are the forerunners of late-blight rot. Even though such a belief is widespread, it is erroneous.

The white specks (figure 35) are nothing more than enlarged breathing pores or lenticels. Every green living plant must be supplied with oxygen. When the soil is full of water, the air which it normally contains and which the tuber needs is forced out; therefore, the lenticels, trying to get all

the oxygen they can, enlarge until the white tissue below is plainly visible as a white weft. Similarly when the tubers are growing fast, even though the soil is relatively dry, the same enlargement takes place. It is thus the sign of a good, healthy potato.



FIGURE 35. A TUBER WITH ENLARGED LENTICELS

When the potatoes are dug, the lenticels dry down to a minute brown speck, or become almost invisible. At no time are they directly associated with the cause of rot.

### HOLLOW-HEART

Aside from numerous possible disease blemishes, the tubers may be made undesirable by the presence of hollow-heart, growth cracks, and knobbliness. These malformations are discussed here because they may be the result of a diseased condition, or their presence on a tuber may supply an entering place for rot-producing fungi and bacteria. This is true particularly when potato skins are broken open by growth cracks or when knobs are broken off of the tuber, thereby leaving a surface exposed to infection.

Hollow-heart is what the name implies. There is no outward sign of its presence, yet when the potato is cut open a central cavity may include a large or small space of the tuber. There is no special shape to the hollow part, and occasionally there may be two small openings instead of one larger one. The lining of the cavities is a grayish brown to dark-brown

layer of cells, which may or may not form a slight cork protection. Sometimes a crack, like a growth-crack, will extend across the tissue surrounding the middle of the hollow heart. A decay is rarely or never associated with the cavity, although it may be found accompanying black-heart, and is then bounded by black tissue.

Nearly every housewife associates hollow-heart with abnormally large tubers. Scientists are inclined to differ in this view and declare that it is not unusual for it to occur in smaller potatoes. Some growers insist that the Rural types of tubers are more given to hollow-heart than are others. It seems, from the information at hand, however, that when any variety grown on a certain soil makes an excellent growth for a time and then is checked suddenly by unfavorable weather, or, if just the reverse is true, there is danger of hollow-heart appearing in the crop. No doubt the type of soil to be avoided is that which generally is considered as poor potato ground.

There are no definite control measures. The precautions outlined for growth cracks and knobiness should be followed, and in addition, the potato hills should be planted close enough together so that in the autumn there will be few over-sized tubers.

### GROWTH CRACKS

Growth cracks are in appearance what their name designates them to be. The cracks may be of any size from those barely visible to those extending the entire length of the potato. They may be arranged cross-wise of the tuber but more often lie in a line between the bud and stem ends. A callous may form over the raw flesh, especially if the crack is fairly shallow and not too wide. If the callosity has time to form before saprophytic molds gain an entrance, the potato may be able to ward off infection entirely; otherwise the surface layer of cells dies and this is followed by decay, or the potato shrivels because it cannot retain its moisture. These growth cracks are related in no wise to the narrow crescent-shaped cracks that occasionally appear on potatoes when too great a pressure is exerted upon them either in handling or in storage. These latter cracks are very characteristic and appear exactly as if the tuber had been pierced repeatedly by a sharp thumb nail.

Growth cracks are not a diseased condition within themselves, but may be symptoms of certain maladies like yellow dwarf. More often, however, they are the expression of unfavorable soil and weather conditions. Investigators are not all agreed in their opinions regarding the exact environment necessary. Certain men believe it is cool wet weather and the consequent fast growth that are responsible for the fissures. Others state that

the blemish is brought about by alternate periods of unusually favorable and unfavorable weather for the growth of the plant. Still others lay the blame on heavy clay soils or poorly tilled lumpy soil. It may be possible that all of these conditions combine in aiding to form the cracks. Apparently the actual cracking is caused by internal stress brought about by unequal development in different parts of the tuber.

From the preceding discussion the following control measures are self evident: (1) use of seed free from yellow dwarf and other destructive diseases, (2) planting only on the best potato soil on the farm, (3) proper tillage and the turning under of sufficient humus to retain the moisture, and (4) good drainage.

### KNOBBY TUBERS

Everyone is familiar with the knobs that grow on the sides or ends of potatoes (figure 36), and which are usually arranged in such a manner that they form grotesque figures. They may almost be cut off from the mother tuber or they may be in the shape of a nipple. Their size, too, is quite variable. The elongation of the stem end to a small point is frequently spoken of as a knob, yet its origin is different and for that reason hardly belongs in the same category.

The cause of knobby tubers is associated either with diseases or with unfavorable growth in the same manner as was suggested for growth cracks. Some varieties of potatoes are more inclined to knobiness than others. Diseases like giant hills and yellow dwarf are known also to stimulate the potato to knob production. Wilt may result in the elongation of the stem end, so that instead of the characteristic stem dimple of the tuber there is a pronounced mound or nipple. The inner tissue of the ordinary knob is normal in color and texture, but the wilt type of knob will have discolored water ducts that may extend for some distance into the tuber.

The control measures are the same as for growth cracks and hollow-heart. In addition it is well to select for seed, varieties that tend toward a smooth, well-shaped potato, instead of an overly large, rough, knobby one.



FIGURE 36. FORMATION OF KNOBS ON TUBERS









